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PROCEEDINGS

OF THE

Forty-Fourth Annual Meeting

Indiana Academy *of* Science

VOLUME 38

1928

J. J. Davis, Editor

S. A. Cain, Assistant Editor

Held at Indiana University

Bloomington, Indiana

December 6-8, 1928

INDIANAPOLIS:

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1929

TABLE OF CONTENTS

Page

Officers and Committees for 1928 ... 5

Past Officers of the Academy ... 7

Minutes of the Spring Meeting ... 8

Winter Meeting ... 10
- Program ... 10
- Minutes of the Executive Committee ... 15
- Minutes of the General Session ... 19

Memorials—
- Edgar K. Chapman: R. R. Ramsey ... 20
- Joseph N. Donahue: J. A. Nieuwland ... 22
- Richard A. Gantz: Fred J. Breeze ... 22
- W. F. N. Goss: Stanley Coulter ... 23
- Louis F. Heimlich: C. L. Porter, et al ... 29
- Frank Senour: E. R. Cumings ... 31
- Joseph Swain: John A. Miller ... 32
- Emerson B. Wright: C. F. Cox ... 34
- Frank C. Wagner: John White ... 35

President's Address—Metals and the Microscope: E. G. Mahin ... 38

Papers on Botany—
- A Contribution to the Phytoecology of Southern Indiana with Special Reference to Certain Ericaceae in a Limestone Area of the Bloomington Quadrangle: Winona H. Welch ... 65
- Bark Formation: F. M. Andrews ... 85
- Variations in Erigeron Annuus: F. M. Andrews ... 86
- A Natural Proof That the Root Tip Alone is Sensitive to the Gravitational Stimulus—II: F. M. Andrews ... 87
- Studies on Pollen—IV: F. M. Andrews ... 89
- Observations Concerning Diseases of Iris and Tulips: E. B. Mains ... 93
- Preservation of Monotropa and Similar Plants without Discoloration: J. A. Nieuwland and A. D. Slavin ... 103
- Peridia of Crucibulum vulgare: Lewis B. Lockwood ... 105
- Algae of Indiana—A Classified Check List of Those Published Between 1875 and 1928: C. Mervin Palmer ... 109
- Tufa Deposits at Clifty Falls State Park: Rexford F. Daubenmire ... 123
- Indiana Fungi—XI: J. M. VanHook ... 127
- Some New Species of Fungi: J. M. VanHook ... 131
- Concerning the Reaction of Certain Fungi to Various Wave Lengths of Light: C. L. Porter and H. W. Bockstahler ... 133
- The Pericycle in the Root of Equisetum: Marion A. Johnson ... 137
- Sodium Chlorate as a Herbicide: Albert A. Hansen ... 139
- Indiana Plant Diseases, 1927: Max W. Gardner ... 143
- Studies of Tomato Quality—IV: Variability in Quality and Food Value of Tomatoes: John H. MacGillivray ... 159
- The Ecology of Turkey Run State Park; Part I—The Flood Plain: Caroline H. Swanson ... 165

Papers on Chemistry and Bacteriology— Page
Mileage Obtained From Some Commercial Gasolines: Edwin M. Bruce 171
Preparation of "Active" Magnesium Carbonate From Magnesite: F. C. Mathers and W. V. Eagleson 175
Comparison of Rust Protection of Iron by Zinc, by Cadmium, and by Zinc-Copper Alloys and the Electrodeposition of such Alloys: F. C. Mathers and R. L. Hardy 183
Esterification in the Presence of Anhydrous Salts: F. M. Whitacre and H. T. Briscoe 187
The Formula of Ethylide Glycerol: J. A. Nieuwland and W. L. Foohey 195
Cuprous Chloride as a Catalyst for Acetylene: J. A. Nieuwland and W. L. Foohey 196
The Oxidation of Benzyl Alcohol by the Three Isomeric Nitrochlorbenzenes: Robert E. Lyons and Guido H. Stempel, Jr 197

Papers on Geology and Geography—
Three Cavern Pictures: Clyde A. Malott 201
The History of the "Hoodoos" near Mammoth Hot Springs, Wyoming: Allen D. Hole 207
Contrasts Among Indiana Counties in Their Yield of Prominent Persons: Stephen S. Visher 217
Some Features of the Upper Surface of the Trenton Limestone in Indiana: William N. Logan 225
Fibrous Marcasite in Crystalline Calcite near Logansport: E. R. Smith and R. A. Schroeder 231
Stratigraphic Units of the Harrodsburg Limestone: Paris B. Stockdale 233
A Striking Case of Differential Erosion: Fred J. Breeze 243
Geological Information From the Monroe and Lawrence County Soil Maps: T. M. Bushnell 245
Special Topographic Features and the Physiographic Background of the Bloomington (Indiana) Quadrangle: Arch R. Addington 247

Papers on Physics and Mathematics—
Lightning, Natural and Artificial: Harvey A. Zinszer 263
The Thermionic Voltmeter as Applied to High Frequency Measurements: J. B. Hershman 269
The Effect of Variations of the Force Function Upon Orbits of Least Action: Oliver E. Glenn 275
A Helical Brass Spring with Constant Pitch Angle: R. B. Abbott 279
Polarization of Radio Waves: R. R. Ramsey and J. J. Brady 281
Photography of Sound Waves: D. L. Eaton 287
A Convenient Method of Showing Anomalous Dispersion: A. W. Dicus. 295

Papers on Zoology—
Some Internal Parasites of Poultry: Otho J. Price 297
Insects of Indiana for 1928: J. J. Davis 299
The Water Mites of Lake Wawasee: Ruth Marshall 315
The Chuck-Wills-Widow in Indiana: Amos W. Butler 321
Comparative Results of Bird Banding in a Large City and a Small Town: F. C. Test and L. A. Test 323

Papers on Zoology—Continued Page
Additional Notes on Summer Birds of Turkey Run State Park: F. H. Test 329
A Preliminary Report on Lernaea, a Copepod Parasitic on the Goldfish: H. E. Enders and S. A. Rifenburgh 333
Records of Indiana Dragonflies—III, 1927-1928: B. Elwood Montgomery 335

List of Members 345

OFFICERS AND COMMITTEES FOR 1928.

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1928	E. G. Mahin	R. C. Friesner	H. F. Dietz	M. W. Lyon, Jr	J. J. Davis
1929	Louis J. Rettger	R. C. Friesner	H. F. Dietz	M. W. Lyon, Jr	

*Deceased. †Officers continued—Annual meeting not held because of influenza epidemic. ‡Listed in year of Proceedings edited.

MINUTES OF THE SPRING MEETING.

LOGANSPORT, INDIANA.

The Indiana Academy of Science met for its regular spring meeting at Logansport, May 17-19, 1928. The meeting was called to order by President Mahin in the American Legion Home at 7:50 p. m., May 17. A motion was passed directing the Committee on Relation of Academy to State to attempt to secure legislation which would make it mandatory that the Governor appoint the nominee of the Academy to the Conservation Commission. President Mahin announced the appointment of J. J. Davis to represent the Academy at the International Congress of Entomologists to be held at Ithaca, New York in August. Upon motion W. N. Hess was also given credentials to represent the Academy at the same meeting. A request of the Ecological Society of America regarding certain National Park matters was referred for recommendation to a committee composed of Charles C. Deam, M. W. Lyon, and F. M. Andrews.

Upon motion the Secretary was directed to send a letter to Colonel Richard Lieber expressing the sympathy of the Academy in the death of his son. Similar letters were directed sent to the families of members who had died since the last meeting. Motion was passed that the Academy express its desire and strong feeling that the State of Indiana should have a public fire-proof museum to house valuable historical and archeological relics which are annually being lost to other states because of our own apathy in the matter. Motion was referred to the Committee on Relation of Academy to State with request to do all in their power to secure proper legislation to care for this matter.

Dr. Weatherwax gave some general directions regarding trips for the following day. Members were then privileged to hear discussions of the geology and history of the Logansport area by Prof. Cumings and Dr. Shrock of Indiana University and Mr. Wilson of Logansport. Meeting adjourned.

Minutes of the Friday Evening Meeting. The committee appointed to consider the request of the Ecological Society regarding legislation relating to certain National Parks recommended that the Academy accede to the desire of the Society. Motion was carried and the Secretary instructed to communicate with the proper persons.

The Committee on Resolutions recommended the following resolution which was unanimously adopted by rising vote:

The Indiana Academy of Science now in its 43rd year and which has been assembled for its Spring Meeting in Logansport desires to express its appreciation of the many courtesies shown all of us during our stay in this city and to express our thanks for the many favors we have received. We desire further to thank the citizens, Professor Cumings, Dr. Shrock, and Mr. Wilson for their instructive talks, and all who have in so many ways made our visit here so pleasant in every way.

F. M. ANDREWS, Chairman.

Upon recommendation of the Membership Committee the following applicants were accepted into membership in the Academy:

Andrews, John Scott, 217 S. Grant St., Lafayette.
Aufderheide, Hellen, 4012 Broadway, Indianapolis.
Boyd, Mary E., 351 North Walnut, Columbia City.
Brooks, Dr. Earl, 139½ N. 9th St., Noblesville.
Coburn, Harry Humbert, 3349 Park Ave., Indianapolis.
Condon, W. Chalmer, R. R. 2, Logansport.
Cox, Alvalon Conway, 1022 N. West, Indianapolis.
Daubenmire, Rexford F., 2325 N. LaSalle St., Indianapolis.
Dawson, Sallie, 807 N. 9th St., Terre Haute.
DeVol, Charles E., 3711 S. Washington, Marion.
Harcourt, Opal, R. R. 3, Rushville.
Haslem, John Robert, 1435 S. 6th, Terre Haute.
Huston, Ernest C., 612 Eagle St., Terre Haute.
Jacobs, Thomas Bingham, 2537 N. 12th St., Terre Haute.
Johnson, William Ainslee, 1121 Maple St., Terre Haute.
Krause, Heinrich, 2938 Normal Ave., Chicago.
Lehman, Rachel Marguerite, R. R. 2, Brazil.
Lloyd, Mrs. W. H., 210 Garfield Ave., Valparaiso.
Lockwood, Lewis Byford, Fort Branch.
Lowe, Grace D., 224 Gilbert Ave., Terre Haute.
Marsh, Homer Floyd, 1303 S. 11½ St., Terre Haute.
McAtee, Waldo Lee, 200 Cedar St., Cherrydale, Va.
McFerran, Harry, 136 W. Linden, Logansport.
Moore, Arthur Everett, 1216½ North, Logansport.
Powers, Roscoe, Route 6, Indianapolis.
Scofield, Robert, Crisman.
Sears, Miss Cecil, 437 N. 5th St., Terre Haute.
Stockdale, Paris B., 219 W. Lane Ave., Columbus, Ohio.
Studebaker, Leo, 1108 Michigan Ave., Logansport.
Stump, Lois Rosamond, R. R. 3, Bloomington.
Wefler, Charles William, 721 National Ave., West Terre Haute.
Wolff, Elizabeth L., 1460 S. 8th St., Terre Haute.
Zimmerman, Harold Alexander, 1213 South Elm St., Muncie.

RAY C. FRIESNER, Secretary.

WINTER MEETING.

PROGRAM OF THE FORTY-FOURTH ANNUAL MEETING OF
THE INDIANA ACADEMY OF SCIENCE
HELD AT
INDIANA UNIVERSITY
BLOOMINGTON, INDIANA
December 6-8, 1928.

THURSDAY, DECEMBER 6, 1928.

9:30 a. m. Meeting of Entomologists of Indiana, Biology Building.

7:30 p. m. Annual Meeting of Executive Committee, Science Hall. Reports of Officers and Committees.

FRIDAY, DECEMBER 7, 1928.

8:00 - 9:00 a. m. Registration, Auditorium of Student Building.

9:00 - 10:30 a. m. General Session, Auditorium of Student Building
Business Session.
Address of Welcome, Dr. John W. Cravens, Indiana University.

IN MEMORIAM—
Edgar K. Chapman, by R. R. Ramsey
Joseph N. Donahue, by J. A. Nieuwland
Richard A. Gantz, by Fred J. Breeze
W. F. N. Goss, by Stanley Coulter
Louis F. Heimlich, by C. L. Porter
Frank Senour, by E. R. Cumings
Joseph Swain, by John A. Miller
Emerson B. Wright, by C. F. Cox
Frank C. Wagner, by John White

10:30 - 12:00 Noon Sectional Meetings.

1:30 - 5:30 p. m. Sectional Meetings continued.

BOTANY.

STANLEY COULTER, Chairman.

A contribution to the phytoecology of Southern Indiana with special reference to certain Ericaceae in a limestone area of Bloomington Quadrangle. Winona H. Welch, Indiana University.

*Psaronius in Indiana and Ohio. J. Hobart Hoskins, University of Cincinnati.

* Not published in this Proceedings.

*A taxonomic monograph of the genus Cuscuta. T. G. Yuncker, DePauw University.

Bark formation. F. M. Andrews, Indiana University.

Variations in Erigeron annuus. F. M. Andrews, Indiana University.

A natural proof that the root tip alone is sensitive to the gravitational stimulus—II. F. M. Andrews, Indiana University.

Studies in pollen—IV. F. M. Andrews, Indiana University.

Observations concerning diseases of iris and tulips. E. B. Mains, Purdue University.

*Hollyhock rust. E. B. Mains, Purdue University.

Preservation of Monotropa and similar plants without discoloration. J. A. Nieuwland and A. Slavin, University of Notre Dame.

Peridia of Crucibulum vulgare. Lewis B. Lockwood, Indiana University.

[1]Algae of Marion County, Indiana, 1928. C. Mervin Palmer, Butler University.

Algae of Indiana—A classified check list of those published between 1875 and 1928. C. Mervin Palmer, Butler University.

*Some ecological factors in secondary succession: Upland hardwood. Ray C. Friesner and Stanley A. Cain, Butler University.

Tufa deposits at Clifty Falls State Park. Rexford F. Daubenmire, Butler University.

Indiana Fungi—XI. J. M. VanHook, Indiana University.

Some new species of fungi. J. M. VanHook, Indiana University.

*Culture methods used in endotrophic mycorrhiza investigations. K. D. Doak, Purdue University.

*A comparison of mycorrhizal structures in roots of the genera Gaylussacia, Vaccinium and Chamaedaphne. K. D. Doak, Purdue University.

. Concerning the reaction of certain fungi to various wave-lengths of light. C. L. Porter and H. W. Bockstahler, Purdue University.

The pericycle in the root of Equisetum. Marion A. Johnson, State Normal.

*The cutting of woody stems in paraffin. Edwin J. Kohl, Purdue University.

*Cleistogamy in a species of Poa. Paul Weatherwax, Indiana University.

Sodium chlorate as a herbicide. Albert A. Hansen, Purdue University.

*Key to the weeds of Indiana. Albert A. Hansen, Purdue University.

*Enumeration of the vascular flora of a limestone area of the Bloomington Quadrangle, Monroe County, Indiana. Winona H. Welch, Indiana University, and Gladys Price, Shorter College, Rome, Georgia.

Indiana plant diseases, 1927. Max W. Gardner, Purdue University.

Studies of tomato quality—IV. Variability in quality and food value of tomatoes. John A. McGillivray, Purdue University.

The ecology of Turkey Run State Park, Part I. The flood plain. Caroline H. Swanson, Crane Tech. H. S., Chicago.

[1] Included with the next paper.

* Not published in this Proceedings.

CHEMISTRY AND BACTERIOLOGY.

W. M. BLANCHARD, Chairman.

Mileage obtained from some commercial gasolines. Edwin M. Bruce, State Normal.

Preparation of "active" magnesium carbonate from magnesite. Frank C. Mathers and W. V. Eagleson, Indiana University.

Comparison of rust protection of iron by zinc, by cadmium, and by zinc-copper alloys and the electrodeposition of such alloys. Frank C. Mathers and R. L. Hardy, Indiana University.

Esterification in the presence of anhydrous salts. Francis M. Whitacre and Herman T. Briscoe, Indiana University.

*Factors determining electrolytic dissociation. Herschel Hunt and Herman T. Briscoe, Indiana University.

*Properties of silicon fluoride and boron fluoride in alcoholic solutions. J. A. Nieuwland and R. R. Vogt, University of Notre Dame.

The formula of ethylidene glycerol. J. A. Nieuwland and W. L. Foohey, University of Notre Dame.

*Agglutinin production: The role which dosage, total amount injected, and frequency of inoculation play. C. A. Behrens, Purdue University.

*The action of alcohols on chromium trioxide. Louis Agassiz Test and Robert C. Gibbons, Purdue University.

*Some chemical and physical properties of hard and soft wheat. R. H. Carr, Purdue University.

The oxidation of benzyl alcohol by the three isomeric nitrochlorbenzenes. R. E. Lyons and G. H. Stempel, Jr., Indiana University.

*The reaction of nitrobenzene with secondary alcohols. R. E. Lyons and M. E. Pleasant, Indiana University.

*The Oxonium theory of acids. W. M. Blanchard, DePauw University.

Cuprous chloride as a catalyst for acetylene. J. A. Nieuwland and W. L. Foohey, University of Notre Dame.

*Preparation of ethylene chloride and vinyl chloride. J. A. Nieuwland, University of Notre Dame.

GEOLOGY AND GEOGRAPHY.

E. R. CUMINGS, Chairman.

*The relation of forests, rainfall and floods. Gerard Fowke, St. Louis, Mo.

*The Pueblo of Atlipac in the Valley of Mexico. W. Leroy Perkins, State Normal.

*The causes of earthquakes and glaciation. Tunis J. Quick, Columbus, Indiana.

Three cavern pictures. Clyde A. Malott, Indiana University.

*Scabland features of the Wabash sluiceway near Logansport, Indiana. Clyde A. Malott and Robert R. Shrock, Indiana University.

* Not published in this Proceedings.

The history of the "Hoodoos" near Mammoth Hot Spring, Wyoming. Allen D. Hole, Earlham College.

*Some new Cenozoic Pectens. Helen I. Tucker, Southern College, Lakeland, Florida.

*Maps of the Indiana Oolitic district. W. N. Logan and Ralph E. Esarey, Indiana University.

Some features of the upper surface of the Trenton Limestone in Indiana. W. N. Logan, Indiana University.

Contrasts among Indiana counties in their yield of prominent persons. S. S. Visher, Indiana University.

Fibrous marcasite in crystalline calcite near Logansport, Indiana. Ernest Rice Smith and Russell A. Schroeder, DePauw University.

Stratigraphic units of the Harrodsburg limestone. Paris B. Stockdale, Ohio State University.

*Reef or Bioherm? E. R. Cumings, Indiana University.

*Fauna of the Kokomo limestone. E. R. Cumings, Indiana University.

A striking case of differential erosion. Fred J. Breeze, Ball Teachers' College.

*A glacial copper nugget found in St. Joseph County. E. G. Mahin, University of Notre Dame.

Geological information from the Monroe and Lawrence County soil maps. T. M. Bushnell, Purdue University.

Special topographic features and the physiographic background of the Bloomington, Indiana, Quadrangle. Arch R. Addington, State Teachers' College, Fresno, Cal.

*The description of soil colors by a factorial color system. J. Gladden Hutton, South Dakota State College, Brookings, S. D.

PHYSICS AND MATHEMATICS.

W. E. EDINGTON, Chairman.

Lightning, natural and artificial. Harvey A. Zinszer, Hanover College.

The thermionic voltmeter as applied to high frequency measurements. J. B. Hershman, State Normal.

*The efficiency of signalling horns. A. L. Foley, Indiana University.

*Erroneous ideas concerning megaphones and trumpet-shaped horns. A. L. Foley, Indiana University.

*Anomalies of sound reflectors. A. L. Foley, Indiana University.

The effect of variations of the force function upon orbits of least action. Oliver E. Glenn, Lansdowne, Pa.

*A study of re-radiated magnetism. R. B. Abbott, Purdue University.

A helical brass spring with constant pitch angle. R. B. Abbott, Purdue University.

*The Literary Digent's Presidential Poll as random sampling. Will E. Edington, Purdue University.

* Not published in this Proceedings.

Polarization of radio waves. R. R. Ramsey and J. J. Brady, Indiana University.

*A new factor in condenser resistance. R. R. Ramsey and B. D. Morris, Indiana University.

*Preliminary report of some experiments on positive-ion ionization. M. E. Hufford, Indiana University.

*A method for making single crystals of zinc. James E. Brock, Purdue University.

*A simplified mercury still. J. B. Dutcher, Indiana University.

*Some observations on thermal insulators. J. B. Dutcher, Indiana University.

Photography of sound waves. D. L. Eaton, Indiana Central College.

A convenient method of showing anomalous dispersion. A. W. Dicus, Indiana University.

ZOOLOGY.

WILL SCOTT, Chairman.

Some internal parasites of poultry. Otho J. Price, Honey Creek High School, Terre Haute.

Insects of Indiana for 1928. J. J. Davis, Purdue University.

*Cytoplasmic studies of the developing eggs of the Toad-bug, Gelastocoris oculatus (A report of work in progress). F. Payne, Indiana University.

The water mites of Lake Wawasee. Ruth Marshall, Rockford College, Rockford, Ill.

*The bottom fauna of Lake Wawasee. Will Scott, Ralph Hile and Herman Spieth, Indiana University.

The Chuck-Will's-Widow in Indiana. Amos W. Butler, Indianapolis.

Comparative results of bird banding in a large city and a small town. Frederick Cleveland Test, Northwestern University, and Louis Agassiz Test, Purdue University.

Additional notes on summer birds of Turkey Run State Park. Frederick H. Test, West Lafayette.

A preliminary report on Lernaea, a parasitic copepod on gold fishes. Howard E. Enders and S. A. Rifenburgh, Purdue University.

*Nesting Habits of the purple martin. K. D. Doak, Purdue University.

*The reproductive cycle in the mammals. G. W. D. Hamlett, Indiana University.

*The spermatogenesis of the Pseudoscorpion (A statement of work in progress). Henry G. Nester, Indiana University.

Records of Indiana Dragonflies—III. 1927-1928. B. Elwood Montgomery, Iowa State College, Ames, Iowa.

* Not published in this Proceedings.

DEMONSTRATIONS.

Exhibit of manuscript on the gall wasp genus Cynips.

Exhibit of galls and gall wasps (Cynipidae). A. C. Kinsey, Indiana University.

Demonstration showing the reticulocyte picture in the rabbit after severe hemorrhage.

Demonstration showing the destruction of red blood corpuscles in lymph nodes. J. A. Badertscher, Indiana University.

Distribution of a few species of Gastropods in the Tippecanoe River System. Herman P. Wright, Indiana University.

MINUTES OF THE EXECUTIVE COMMITTEE.

The Executive Committee was called to order at 7:50 p. m. Dec. 6, 1928, in Science Hall. The following members were present: F. M. Andrews, C. A. Behrens, W. M. Blanchard, A. W. Butler, W. A. Cogshall, Stanley Coulter, E. R. Cumings, J. J. Davis, C. C. Deam, H. F. Dietz, H. E. Enders, A. L. Foley, R. C. Friesner, M. W. Lyon, E. G. Mahin, E. B. Williamson, J. S. Wright.

Reports of officers followed:

Academy Foundation.—Chairman Butler presented the following report:

December 1, 1927, balance on hand	$ 9.40
Total receipts, interest and additions by Academy	493.94
Total	$ 503.34
Investments made during the year	400.00
Balance on hand December 1, 1928	$ 103.34

ASSETS.

U. S. 4th L. L. Bond	$ 50.00
Muncie Masonic Temple, Preferred	200.00
Railroadmen's Bldg. and Sav. Assoc., 17 shares	1,700.00
Balance as shown above	103.34
Total Assets	$2,053.34

Archeological Survey.—Chairman Logan reported that 169 specimens were classified and added to the collection, thus bringing the total specimens for the past nine years to 4,524. Over 400 pages of typewritten abstracts were also prepared.

Auditing Committee.—Chairman Edington reported that the books of both the Treasurer and the Editor had been audited and found to be correct.

Biological Survey.—Chairman Dietz reported that a questionnaire had been mailed to all members of the Academy and a more detailed report would be made from the results of these.

Editor.—Editor Davis reported as follows:

Volume 37 of the Proceedings of the Indiana Academy of Science was distributed August 13, 1928. The cost of the Proceedings for the past five years has been as follows:

	1923	1924	1925	1926	1927
Cost	$1,282.18	$1,668.64	$1,404.80	$1,402.91	$2,130.20
No. of copies	1,000	1,300	1,300	1,300	1,500
No. of pages	336	428	393	364	516
No. of cuts	74	107	61	69	155
Kind of binding	Paper	Cloth	Cloth	Cloth	Cloth

The financial report, not including clerical help and other editorial expenses, as follows:

RECEPTS.

Balance from 1927 (See Proceedings for 1927, p. 19)	$ 11.74
Received from 1926 Proceedings reprints	37.40
Received from 1927 Proceedings reprints	354.55
Interest	.33
Total receipts	$ 404.02

DISBURSEMENTS.

Wm. B. Burford for extra reprints	$ 84.80
Express, postage, etc. not charged elswhere	9.36
Total expenses	$ 94.16
Balance in Purdue State Bank	309.86
	$ 404.02

LIABILITIES.

Cost of 1927 Proceedings	$2,130.20

ASSETS.

Amount due from State	$1,500.00
Balance in Reprint Fund	309.86
Paid by Academy Treasurer	200.00
Amount due from authors for reprints	12.00
	$2,021.86
Deficit	$ 108.34

In spite of care used in selecting papers for the last Proceedings, the cost exceeded our income. This was due to the increased number of papers submitted and printed and to the increased number of copies printed which was essential and was authorized by the Academy. We did not publish the facsimile reproduction of the signatures of the original constitution as authorized by the Academy. There seemed to be little value of such a reproduction compared to the value of scientific papers available for the Proceedings and the Editor feels that if the

Academy authorizes printing these signatures that a special fund be set aside for this purpose.

Because of the deficit in the Editor's funds, very careful selection will be necessary to take care of this item and avoid a deficit in 1929.

Membership.—Chairman Enders reported 86 applications at this time. Reading of names was deferred until a later meeting.

Press Secretary.—Chairman Dietz thanked the newspapers of the State and the Department of Journalism of Indiana University for the excellent publicity service which they have given the Academy. He called attention to the fact that authors are not co-operating with him by way of including abstracts of their papers.

Program Committee.—Chairman Weatherwax presented the program of meetings and papers for Friday and Saturday.

Relation of Academy to State.—Chairman Wallace reported that the committee is preparing to request the State Legislature to make appropriation for a museum building.

Research Committee.—Chairman Foley called attention of members of the Academy to the fact that they could help the Research Committee if each member of the Academy would supply the Committee with names of people in his community or other communities in which he may be acquainted, who might be interested in establishing research scholarships and fellowships. He pointed out that such fellowships can be established for comparatively small sums and that such memorials do not appeal to the rich only. An enduring and at the same time useful memorial can be provided for the cost of a small slab of marble. Worthy students can be aided and science advanced for sums easily within the reach of many people who would gladly provide such sums if they but realized the far-reaching benefits which their generosity would bring to their fellowmen.

State Library Committee.—Chairman Dietz called attention to the impaired facilities of the State Library resulting from the overcrowded condition. He pointed out that now is the time to follow up the resolution adopted by the Academy last year favoring a new library building.

Treasurer.—Treasurer Lyon made the following report:

INDIANA ACADEMY OF SCIENCE.

Report of Treasurer for Year 1928.

RECEIPTS DURING CALENDAR YEAR.

Balance on hand January 1, 1928	$505 84
Collected from members, dues and initiation fees	1,004 00
Donation, part expenses of Winter Meeting for 1927	10 00
American Association for Advancement of Science	104 00
	$1,623 84

DISBURSEMENTS DURING CALENDAR YEAR.

Academy Foundation		$304 00
President's Office		6 10
Clerical expenses	$2 10	
Postage	4 00	
Secretary's Office		192 50
Clerical expenses	$5 02	
Stationery and Printing (1)	57 40	
Postage (2)	121 50	
Miscellaneous	8 58	
Treasurer's Office		76 76
Clerical expenses	$24 28	
Stationary and Printing	26 20	
Postage	26 28	
Editor's Office		200 00
Printing Proceedings in part	$200 00	
Program Committee		175 46
Printing	$88 71	
Postage	69 00	
Miscellaneous	17 75	
Committee on Biological Survey		14 09
Printing	$14 09	
		$968 91
Balance on hand December 31, 1928		$654 93
		$1,623 84

Treasurer Lyon recommended that $200 be set aside from the general fund of the Academy to be added to the Research Endowment Fund, in addition to the $104 received from the American Association for the Advancement of Science.

New Business.—Dean Coulter moved that the time of the winter meetings be changed to the Friday and Saturday following Thanksgiving. Motion was tabled.

It was moved, seconded, and carried that a committee of one be appointed by the President to confer with similar committees of the Indiana Historical Society, and the Indiana Horticultural Society to set dates of the winter meetings in order to avoid conflicts—this committee to report at the spring meetings.

Dr. Lyon moved that the Academy extend, in cooperation with the Indianapolis Chamber of Commerce, an invitation to the American Association for the Advancement of Science to hold their meetings at Indianapolis at their open date. Motion carried.

Moved, seconded, and carried that non-resident charter members receive copies of the Proceedings gratis upon application.

Upon motion duly seconded and carried the Treasurer was requested to pay $108.34 to the Editor's account.

[1] Includes letter heads and envelopes for all offices and standing committees.

[2] Includes $100.00 for Proceedings mailed by State Librarian.

It was moved, seconded, and carried that the Representative of the Academy on the Council of the American Association for the Advancement of Science should be added to the list of committees to be appointed by the President.

Meeting adjourned.

MINUTES OF GENERAL SESSION

DECEMBER 7, 1928.

Minutes of Executive Committee were read and approved.

Dr. Markle conveyed to the Academy the invitation of Earlham College to hold the next winter meeting at that institution. The invitation was accepted with thanks.

Chairman Foley of the Committee on Nominations reported the following members for Fellows and Honorary Fellows:

For Fellows:

Charles P. Emerson, Indiana Univ. School of Medicine, Indianapolis.
Melvin G. Mellon, Purdue University, Lafayette.
Stanley A. Cain, Butler University, Indianapolis.
Harvey A. Zinszer, Hanover College, Hanover.
Charles L. Porter, Purdue University, Lafayette.

For Honorary Fellows:

David Starr Jordan, Stanford University, Stanford, California.
John Merle Coulter, 306 Broadway, Yonkers, New York.
Stanley Coulter, Ambassador Apartment Hotel, Indianapolis.

This report was unanimously adopted by the Academy.

Dr. John W. Cravens gave the address of welcome to the Academy after which the regular program of papers followed.

At a brief business session following the Annual Academy Dinner the following business was transacted:

The Nominating Committee made the following recommendations for officers for 1929:

President, L. J. Rettger, Indiana State Normal School, Terre Haute.
Vice-President, J. A. Nieuwland, Univ. of Notre Dame, Notre Dame.
Secretary, Ray C. Friesner, Butler University, Indianapolis.
Treasurer, M. W. Lyon, Jr., The Clinic, South Bend.
Editor, J. J. Davis, Purdue University, Lafayette.
Press Secretary, H. F. Dietz, State Ent. Office, Indianapolis.

The report was adopted and the above candidates were declared elected.

The Membership Committee reported 114 applications for membership in the Academy. These names were read and voted into membership. Their names will be found upon the membership roll for the year—in this volume of the Proceedings.

The Academy voted its thanks to Indiana University for its hospitality during these meetings.

RAY C. FRIESNER, Secretary.

EDGAR KINCAID CHAPMAN.

HUNTLEY, ILLINOIS. December 28, 1877.

CRAWFORDSVILLE, INDIANA. November 3, 1928.

Edgar Kincaid Chapman was born in Huntley, Illinois, December 28, 1877. A few years later he moved with his parents to Iowa, where he lived on a farm and attended the public schools, graduating from the Independence (Iowa) High School.

In 1903 he received the A.B. degree from Oberlin College. In 1910 he received the degree Sc.M. from Chicago University. In 1919 he began graduate work at Indiana University toward his Ph.D. degree.

EDGAR KINCAID CHAPMAN.

In 1922 when he was stricken he had this work well towards completion. While attending Chicago University he was a member of the Acacia fraternity. His scholarship at Chicago is attested by the fact that he was elected to the honorary scientific society, Sigma Xi.

After graduating from Oberlin College he taught in the South Whitley (Indiana) High School, 1903-04; Garrett (Indiana) High School, 1904-05; DeKalb (Illinois) High School, 1905-06. He held the position of Professor of Physics in Iowa State Teachers' College, Cedar Falls, Iowa, during the years 1906-09. In 1910 he was elected Professor of Physics at Wabash College, and held the position until his death. During the year 1918-19 he was an instructor in the U. S. School for Radio Mechanicians at Indiana University.

Professor Chapman was preeminently a teacher. He was able to impart to the student his enthusiasm and his clear conception of the subject taught. It has been said that the true student and teacher will always get together; this was true in Chapman's case. During his latter years when he was unable to attend classes, advanced students came to his home. Often he held classes in his room when he was unable to leave his bed.

Professor Chapman was a leader in the faculty of Wabash College and did a great deal to advance the cause of science. He was one of the

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

organizers of the Science Club at Wabash College and applied to the general organization of Sigma Xi for the right to call the club a Sigma Xi club. This being a new idea to the Sigma Xi Council, the permit was granted after a number of years. His standing as a man of science at Wabash is shown by the fact that he was able to convince the President and the Board of Trustees that it was a good thing for Wabash to share the expenses of the faculty to scientific meetings.

He was a member of the American Physical Society and soon after coming to Indiana he joined the Indiana Academy of Science (1911). Although he did not read many papers, he was a regular attendant of the meetings during the early years of his stay in Indiana. The minutes of the Academy show that he read a paper on "The Spectrum of Phosphorescent Mercury" in 1919. Among his papers is found an abstract of a paper for the American Physical Society.

Early in life Professor Chapman identified himself with the Congregational Church. At Crawfordsville he united with the denomination of his choice and was a member until the congregation merged into the Presbyterian Church. In the Presbyterian Church he was a member of the official board. For some time he was the director of the choir of the Baptist Church. Thus he was officially connected with three Crawfordsville churches, and the membership of all three respected and loved him.

Up until he was impaired in health he and his family spent the summers on Bass Lake, near Pentwater, Michigan. Here he was the life of the community. All the farmers and fishermen in the neighborhood knew Professor Chapman. Here he could roam the woods, climb the dunes, and penetrate into the mysteries of Devil's Pond. He knew the quality of the blueberries on the high hills, and the time of ripening of the blackberries in the low valleys. He was an ardent disciple of Izaak Walton. If there was a bass or pickerel any place in the lake that would bite, Chapman caught it. He systematically worked his boat from one end of the lake to the other, casting all the time. The logs were never so high or the brush so thick on a trout stream that he could not worm himself through and get his line in the pool. He was a lover of the great out of doors. Professor Chapman was at his best when he was cooking a "beach supper" over an open fire on the shore of Lake Michigan.

The one word which describes him is the word enthusiasm. Whether it was work or play, he entered in with his whole soul.

During his last years, although he was for months at a time confined to his bed, often suffering severe pain, he was always cheerful and hopeful. He was interested in the affairs of the home, town and college to the end.

In the passing of Edgar Chapman, Wabash College has lost a teacher, the State of Indiana has lost a true man, and we have lost a friend.

R. R. RAMSEY, Indiana University.

JOSEPH N. DONAHUE, C. S. C.

SOUTH BEND, INDIANA. February 26, 1889.

SOUTH BEND, INDIANA. July 27, 1928.

Father Donahue was born February 26, 1889 in South Bend, Indiana. He attended St. Joseph's parochial school, where he obtained his elementary education, graduating at the age of 14. At this early age, he entered Holy Cross Seminary at Notre Dame University. After receiving his undergraduate degree from Notre Dame, Father Donahue attended the Catholic University at Washington, D.C., where he studied four years. He was ordained into the priesthood at Notre Dame, in June, 1916, and said his first mass in the parish of his childhood—St. Joseph's of South Bend.

From 1916 to 1920 he attended the Massachusetts Institute of Technology, Boston, Massachusetts, receiving the degree of Master of Science in mathematics from this institution in 1920.

Returning to Notre Dame, he was made a professor of physics and mathematics, which positions he held for two years. In 1922, he received his appointment to Columbia University at Portland Oregon where he was Director of Studies. In 1925, he was elevated to the presidency of the same institution, which position he held for a full three-year term.

While visiting relatives in the city of his birth, Father Donahue was removed to St. Joseph's Hospital for peritonitis. He died July 27, 1928.

J. A. NIEUWLAND, Notre Dame University.

RICHARD A. GANTZ.

SALINE CITY, INDIANA. March 18, 1879.

MUNCIE, INDIANA. October 2, 1928.

Richard A. Gantz, Professor of Physiology and Biology in Ball Teachers College, died at his home in Muncie, October 2, 1928. He is survived by his widow, three daughters, and one son.

RICHARD A. GANTZ.

Professor Gantz was born at Saline City, Indiana, March 18, 1879. He completed his high school course at the Terre Haute High School, and graduated from the Indiana State Normal School in 1904. He received his A.B. degree from the University of Michigan in 1912, and his M.S. degree from the University of Illinois in 1918. While at these universities he served as a laboratory assistant in Biology.

For six years he taught in the rural and graded schools of Indiana. He was principal of the Farmersburg High School from 1906 to 1909. From 1912 to 1913 he was Professor of Biology in Mercer University. At the Warrensburg State Normal School, Warrensburg, Mo., he served as Professor of Biology from 1913 to 1916. From 1918 to 1919 he was acting Professor of Biology at Georgetown University, Georgetown, Ky. He came to Ball Teachers College in 1919 and served that institution loyally and efficiently to the day of his death. During these years at Muncie he fought vigorously and fearlessly for every movement leading to better community health, especially the health of the students.

Professor Gantz was a member of the Indiana Academy of Science, the Illinois Academy of Science, the American Public Health Association, and the Izaak Walton League. He was also an active member of the Methodist Episcopal Church.

PUBLICATIONS BY RICHARD A. GANTZ.

"Finds of the American Mastodon (*Mammut americanum*) in Delaware County, Indiana."—Proc. Ind. Acad. Sci., vol. 34, 1924 (1925).

"A Plea for John R. Kissinger."—Proc. Ind. Acad. Sci., vol. 37, 1927 (1928).

"Biology and Higher Education."—Trans. Illinois State Acad. Sci., vol. 20, 1927 (1928).

"A Study of Schoolroom Ventilation Involving a Comparison of Two Types of Heating and Ventilating Plants." (With Harriet Thornhill Phypers.)—Proc. Ind. Acad. Sci., vol. 37, 1927 (1928).

"Laboratory Exercises for Physiology and Personal Hygiene."

"Laboratory Exercises for Physiology (Public Health)."

"Manual for General Biology."

FRED J. BREEZE, Ball State Teachers College.

WILLIAM FREEMAN MYRICK GOSS.

BARNSTABLE, MASSACHUSETTS. October 7, 1859.

NEW YORK, NEW YORK. March 23, 1928.

Certificate, Massachusetts Institute of Technology, 1879; Honorary Master of Science, Wabash College, 1888; Doctor of Engineering, University of Illinois, 1904; Instructor, Mechanic Arts, Purdue University, 1879-83; Professor, Practical Mechanics, Purdue University, 1883-89; Professor, Experimental Engineering, Purdue University, 1889-1907; Director, Engineering Laboratory, Purdue University, 1899-1907; Dean, School of Engineering, Purdue University, 1900-07; Dean, College of Engineering and Director, School of Railway Engineering and Administration, University of Illinois, 1907-17; Director, Engineering Experi-

ment Station, University of Illinois, 1909-17; President, Railway Car Manufacturers Association, 1917-1925; Chief Engineer, Chicago Association of Commerce Committee, 1913-16; Jury Awards, Columbian Exposition, 1893; National Advisory Board, Fuels and Structural Materials, 1905; Chairman, Engineering Foundation, 1919-20; Member or Fellow: Am. Soc. Mech. Eng. (Past President); Am. Soc. El. Eng.; Soc. Eng. Education; Western Soc. Eng.; Western Rwy. Club; Ind. Acad, Sci.; Ill. Acad. Sci.; Ill. Soc. Eng.; International Assoc. of Testing Materials.

W. F. M. Goss.

It is unfortunate that limitations of space preclude any adequate presentation of the life and services of Doctor Goss. Very few of those who have served Indiana in educational and scientific lines have exerted so profound and lasting an influence. Coming to Indiana in his early manhood, he laid the foundations upon which arose the School of Engineering at Purdue University, and in a remarkably short time brought it to the front rank in the country. While he was at work organizing and developing the school, he was able to find time to improve engineering practice, to institute new experimental methods, to publish numerous books and papers, and to serve his profession upon the working committees of various engineering societies. It was inevitable that he should become one of the great engineers of his generation; that his word should carry weight both in engineering education and in engineering practice. The summary which serves as foreword to this brief appreciation gives evidence of the recognition of his knowledge and skill, while the bibliography with which it closes proves that there could have been but few idle moments in his achieveing life.

Of fine New England lineage, his forbears holding high positions of trust and honor in their native state, he had in full measure all of the fine qualities that such a heritage insures.

To those of us who knew him intimately, he was a modest, unassuming, friendly man, with an infinite capacity for work and an almost uncanny genius for organization. Apparently everything he undertook worked, for after his plans were once laid, he carried them to completion with a persistent dynamic force that was as characteristic as his genius for organization. He never pushed himself to the front, but the nature and quality of his work was such that he could not avoid prominence.

While kindly, he was firm, never willing to compromise in matters which seemed to him to involve moral cleanness or scientific honesty; at the same time he was never unfair or discourteous to those from whom he differed.

While in his later years the scene of his activities was, in the main in other states, his basic work, the winning of his high position in his chosen field, were the product of his Indiana years. That in his heart he still turned back to Indiana is shown by his leaving to Purdue University his Engineering Library of nearly 1,000 titles, among which are 750 bound volumes. To be known as the "Doctor Goss Engineering Library," it will stand as a constant reminder of his great services to Purdue University and to the state.

It might be supposed that in a life so compact of effective work, no time would be found for other problems than those arising in engineering and education, yet into civic movements, into church and other activities, he brought the same skill in organization, the same power of execution. His was a life of work done squarely and unwasted days.

It is hard for one who holds him so dear to speak without some danger of exaggeration, but to this Academy, to education and to science, his passing is an irreparable loss. A rare personality, working quietly, persistently, effectively, winning friends and fame by his loyalty to what to him was the best. He could leave us no greater lesson, no sweeter memory.

PUBLICATIONS BY WILLIAM FREEMAN MYRICK GOSS.[1]

I. Books and Reports Published in Bound Form.

Bench work in wood: A course of study and practice design for the use of schools and colleges. 161 p. Boston, 1888. Rev. Ed. 1905.

Locomotive sparks. 172 p. New York, 1902.

Locomotive performance; the result of a series of researches conducted by the Engineering Laboratory of Purdue University. 439 p. New York, 1907.

Tests of a Jacobs-Shupert boiler in comparison with a radial-stay boiler. 171 p. Coatesville, Pa., Jacobs Shupert United States Firebox Company, 1912.

Smoke abatement and electrification of railway terminals in Chicago, a report. 1,177 p. Chicago, 1915.

[1] Compiled by William M. Hepburn, Librarian of Purdue University.

II. PAPERS IN JOURNALS.

Description of the Purdue University Experimental Locomotive. Trans. Amer. Soc. Mech. Eng., *13:* 427-437. 1892.

Notes concerning tests of the Purdue Experimental Locomotive. Proc. Ind. Acad. Sci. 1892: 24-25.

Tests of the Locomotive at the Laboratory of Purdue University. Trans. Amer. Soc. Mech. Eng., *14:* 826-848. 1893.

The value of the steam pipe within the smoke box of a locomotive, as a means of superheating. Proc. Ind. Acad. Sci., 1893: 271-273.

An experimental study of the action of the counterbalance in locomotive drive-wheels. Proc. Ind. Acad. Sci., 1893: 273-274.

An experimental study of the effect of the counterbalance in locomotive drive-wheels upon the pressure between wheel and rail. Trans. Amer. Soc. Mech. Eng., *16:* 305-316, 1894.

The Purdue Engineering Laboratory since the restoration. Proc. Ind. Acad. Sci., 1894: 39-40.

The Purdue University Locomotive Testing Plant. Purdue University, Lafayette, Ind., 1895: 11, 5 pls.

A glimpse of the exhaust jet. Proc. Western Rwy. Club. 1895: 85-89.

Strains in steam machinery. Proc. Ind. Acad. Sci., 1895: 75-77.

New forms of Friction Brakes. Trans, Amer. Soc. Mech. Eng., *16:* 806-819, 1895.

Tests of a ten horse-power De Laval Steam Turbine. Trans. Amer. Soc. Mech. Eng., *17:* 81-89, 1895.

Notes concerning the performance of the Purdue Locomotive "Schenectady." Proc. Western Rwy. Club, 1896: 390-398.

The effect, upon the diagrams, of long pipe-connections for steam engine indicators. Trans. Amer. Soc. Mech. Eng., *17:* 398-412, 1896.

The effect of high rates of combustion upon the efficiency of locomotive boilers. Proc. N. Y. RR. Club, 1896: 6-23.

Paper Friction Wheels. Trans. Amer. Soc. Mech. Eng., *18:* 102-110, 1896.

The Engineering Research Laboratory in its relation to the public. Proc. Ind. Acad. Sci., 1896: 59-63.

Tests of a wrought iron car axle. Proc. Ind. Acad. Sci., 1896: 88-93.

Exhaust pipes and steam passages. Daily Railway Age, June 23, 1896: 27-34.

Indicator diagrams from the Experimental Locomotive of Purdue University. The Railway Review, December 19, 26, 1926, Jan. 2, 9, 16, 23, 30, 1897.

Test of a wrought-iron car axle. Digest of Physical Tests, *2:* 85-95. April 1897.

Speed of rotation for locomotive engines. Baker's Rwy. Mag., July 1897: 52-57.

Atmospheric resistance to the motion of railway trains. Proc. Western Rwy. Club, 1898: 347-377.

Reports of tests made on a vertical triple expansion crank and fly wheel pumping engine having a daily capacity of 20,000,000 U. S. gallons. July, 1898: 76.

Tests of coal for locomotives. Proc. Western Rwy. Club, 1898: 115-129.
Performance of the Twenty-Million-Gallon Snow pumping Engine of the Indianapolis Water Company. Proc. Ind. Acad. Sci., 1898: 147-149.
Tests to determine the efficiency of locomotive boiler coverings. Proc. Ind. Acad. Sci., 1898: 149-151.
Tests of locomotive boiler covering. Proc. Western Rwy. Club, 1899: 162-182.
Test of the Snow pumping engine at the Riverside Station of the Indianapolis Water Company. Trans. Amer. Soc. Mech. Eng., *21:* 793-824. 1900.
Tests of the Boiler of the Purdue Locomotive. Trans. Amer. Soc. Mech. Eng., *22:* 453-487, 1900.
Some factors affecting the power of locomotives. Proc. New England Railroad Club, 1901: 6-50.
Possibilities in American locomotive design. Railroad Gazette, October 17, 1902.
The training of an engineer, or the work of students in a technical school. Proc. St. Louis Rwy. Club, 1902: 9-27.
The Master Car Builders' drop-testing machine as installed at Purdue University. Proc. Amer. Soc. Testing Materials, *3:* 256-261, 1903.
Progress in locomotive testing. Proc. Ind. Acad. Sci., 1903: 113-115.
Recent progress in the design of locomotive front-ends. Proc. Central Railway Club, 1903: 6-22.
A series distilling apparatus of high efficiency. Trans. Amer. Soc. Mech. Eng., *25:* 160-175, 1903.
Report of standing committee on Tests of M.C.B. Couplers. Proc. Master Car Builders' Assn., *37:* 190-210, 1903.
Locomotive valve and valve gears. Proc. Southern and Southwestern Rwy. Club, 1904: 10-33.
The technical graduate and the machinery department of railroads. Proc. Western Rwy. Club, 1904: 202-209.
Locomotive testing plants. Trans. Amer. Soc. Mech. Eng., *25:* 827-867, 1904.
The plans for testing locomotives at the Louisiana Exposition. Proc. Ind. Eng. Soc., 1904: 54-55.
Superheated steam in locomotive service. Purdue Eng. Rev., 1905: 7-10.
Locomotive performance under a steam pressure of 250 pounds, an investigation conducted under the patronage of the Carnegie Institution. Railroad Gazette, *38:* 651-652, June 9, 1905.
Report of the standing committee on Brake Shoes. Proc. Master Car Builders' Assn., *40:* 137-173, 1906.
Report of the committee on Brake Beams. Proc. Master Car Builders' Assn., *40:* 179-288, 1906.
Locomotive front-ends. Proc. Amer. Rwy. Master Mechanics' Assn., *39:* 237-330, 1906.
Steps in the development of a smokeless city. Proc. Ind. Acad. Sci., 1906: 71-76.
A study in graphite. 43 p. Joseph Dixon Crucible Company, Jersey City, 1907.

The Cole locomotive superheater. Trans. Amer. Soc. Mech. Eng., *29:* 289-294, 1907.

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III. Numerous other articles by Doctor Goss have appeared in technical journals. In many cases they were based on the research work recorded in greater detail in the papers listed in Part II above.

STANLEY COULTER, Indianapolis.

LOUIS FREDERICK HEIMLICH.

REYNOLDS, INDIANA. April 13, 1890.

VALPARAISO, INDIANA. October 12, 1928.

The death of Dr. Louis F. Heimlich occurred at Valparaiso, Indiana, on October 12, 1928, following a very short illness from penumonia.

Doctor Heimlich was born at Reynolds, Indiana, in 1890. His early education was received in the public and Lutheran parochial schools of Monticello and Lafayette, Indiana. He entered Purdue University in 1910. His major studies lay in the botanical field. In 1914 he received his B. S. degree and in 1916 his M. S. degree. In order to continue advanced work in botany he spent several summers at the University of Wisconsin and an entire year's residence in 1924. He received his Ph. D. from the University of Wisconsin in June, 1926.

Immediately upon his graduation from Purdue University, Doctor Heimlich became an assistant instructor in the Department of Biology at Purdue University. After receiving his M. S. degree he became an instructor in Botany. In 1923 he was raised to the rank of Assistant Professor of Botany. His greatest field of activity at this time was along taxonomic and morphological lines. He was very active making collections of the native flora and studying variations in the local flora. His first contributions were the result of such efforts. It was the result also of this concentrated taxonomic work that gave him such an intimate knowledge of the local Indiana flora with which to enable him to revise and construct a taxonomic key of great value in class use. The key was published privately. A revision of this work was in progress at the time of his death.

Very soon after his return from the University of Wisconsin, he received an invitation from the authorities at Valparaiso University to join their staff. This offer was coincident with the purchase of the University by the Missouri Synod of the Lutheran church. In 1926 Doctor Heimlich accepted their invitation and became Head of the Department of Biology. He was Dean of the University during the year 1927. At Valparaiso University, he reorganized the instructional work in Botany and went about in his tireless way of setting up a fine and efficient teaching organization.

The removal of a young, virile and tireless worker from our midst staggers us all. Doctor Heimlich seemed just at the prime of his life. He had planned long and hard for what he considered great things. He was devoted heart and soul to his botanical work. He had just purchased 15 acres of wooded land overlooking and fronting a lake in northern Wisconsin. This was, as he termed it, a veritable botanical paradise, and his plans for its occupancy during vacations reveals the real botanist.

Louis F. Heimlich will be long remembered at Purdue University as a student and a teacher. He impressed us with his zeal for accuracy, his untiring efforts in an honest portrayal of facts, his keen perception and his skill in delineating the facts. He was a technician and artist of great skill. The administration of his botanical work was marked by the same earnest devotion in getting his subject to his student. He spared no pains in preparing his lectures. He was liked and respected by his students to a very great degree. By his colleagues, he will be remembered as an amiable co-worker. He was unassuming in manner and possessed of a keen sense of humor. He was a great exponent of the truth and the pursuit of it was a great joy.

Doctor Heimlich's ability as an executive was demonstrated by the rapid and efficient organization of the Department of Biology at Valparaiso University. His adoption of high standards and ideals testify to the work of a great teacher and to the efforts of a tireless administrator. His students and co-workers were instilled with an unwavering confidence and loyalty. The soundness of his planning at Valparaiso will become more apparent as the years pass by.

Doctor Heimlich was an earnest and devoted Christian. He was a member of the Lutheran Church and as such was a great worker in the church. He was a very greatly interested and an active worker in the Lutheran National Educational Association.

PUBLICATIONS OF LOUIS F. HEIMLICH

"The Primrose-leaved violet in White County."—Proc. Ind. Acad. Sci. 30: 213-217. 1914.

"The trees of White County, Indiana."—Proc. Ind. Acad. Sci. 33: 387-474. 1917.

"Native plants of White County III."—Proc. Ind. Acad. Sci. 36: 219-224. 1920.

"Peloria in Linaria and other plants."—Proc. Ind. Acad. 37: 111, 116. 1921.

"Plants of White County IV."—Proc. Ind. Acad. Sci. 37: 117-119. 1921.

"Plants of White County V."—38: 281-289. 1922.

"Plants of White County VI."—39: 225-231. 1923.

"The development and anatomy of the staminate flower of the cucumber."—Am. Jour. Bot. 14: 227-237. 1927.

"Michosporogenesis in Cucumis sativus."—In La Cellule, in press.

FRED KAUFMANN, Valparaiso University.
EDWIN J. KOHL.
C. L. PORTER, Purdue University.

FRANK C. SENOUR.

NEW AUGUSTA, INDIANA. December 15, 1871.

INDIANAPOLIS, INDIANA. November 2, 1928.

Frank C. Senour was born December 15, 1871, at New Augusta, Marion County, Indiana, and died in Indianapolis, November 2, 1928, of paralytic shock. He attended the country school near his home and the New Augusta High School, and later while teaching in the same high school attended Indiana University, mainly during summer sessions. He received the A. B. degree from Indiana University in 1911 and the A. M. degree in 1913. He had already become a well-known figure in the secondary school system of the state.

In 1911 he was appointed Instructor in English at Indiana University. He became assistant professor in 1917 and associate professor in 1923, which position he held until the time of his death. He was married to Miss Helen George, August 25, 1928.

Professor Senour was a rare spirit. He came to be known among the students of the University as the most versatile man on the campus—his reading and knowledge ranging through the fields of literature, art, philosophy and science. Set off by his extraordinary modesty, his accomplishments were all the more remarkable to those who had the good fortune to know him intimately; and such were few indeed. When Prof. Charles D. Campbell, former head of the School of Music, passed away rather suddenly, Frank Senour was the only man in the faculty who could take up his courses and conduct them in an acceptable fashion. His series of unsigned articles in the Daily Student on art made a profound impression not only for their high literary merit, but as a revelation of his deep and intimate knowledge of the subject. I have heard President Bryan say that Senour was one of the best informed men in the field of philosophy that he had known. I can vouch for his knowledge and understanding in the scientific field. During the stressful days of the S. A. T. C., when we were at our wits' end to find instructors to teach the hordes of boys in barracks, I asked Senour to take a section of physiography. He taught it with enthusiasm and complete success. I knew he could do it, for years before I had seen his enthusiasm on my field trips. He never lost his interest in geology and physical geography and must have read rather widely in that field.

Because of Professor Senour's interest in science he was elected by the Indiana chapter of Sigma Xi a permanent guest of the chapter, and he attended most of our meetings thereafter. At the suggestion of his scientific friends at the University he became a member of the Indiana Academy of Science in 1922.

Senour abhorred sham and show; and of publicity—that pampered darling of the modern world—he would have none. He shrank from any sort of office or anything that brought him conspicuously before the public. He would never accept the presidency of the Faculty Club, although it was repeatedly tendered him; but if there was any service he could render the Club he gave himself unstintedly to it.

In his teaching he broke through pedantry and dilettantism and got

down to reality. He saw English literature in relation to life. He prodded students into thinking, if they were able to think—and there *are* a few such. I fear this was a cause for some grumbling, for even those who can think dread to do it.

Professor Senour sometimes impressed strangers as being austere or even brusque. His impatience with superficialities accounts for most of this impression, and a certain moodiness for the rest. He did have spells of dejection; and not without reason. He was not always appreciated as a man of his genuine worth should have been. In reality he had a gentle soul, a rare sense of humor, and the ability to win and hold the sincerest affection of those who knew him best. He was a teacher and a philosopher and a devoted lover of the beautiful things of the world of nature and of art. When I think of him I think of the words of his distinguished friend the artist Theodore Steele: "Every day I take off my hat to the beauty that is in the world." That was his creed.

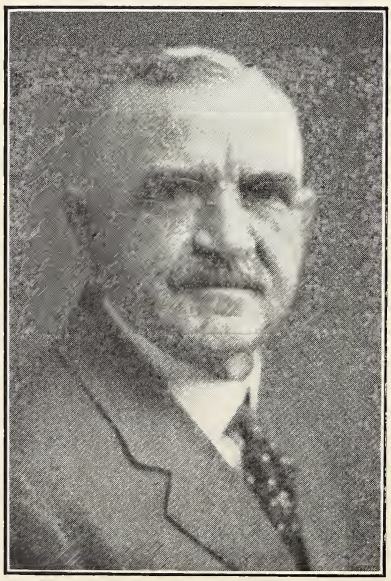
E. R. CUMINGS, Indiana University.

JOSEPH SWAIN.

PENDLETON, INDIANA.	WALLINGFORD, PENNSYLVANIA.
June 16, 1857.	May 19, 1927.

Joseph Swain was born at Pendleton, Indiana, June 16, 1857. He died in Wallingford, Pennsylvania, May 19, 1927.

He was of Quaker parentage, and was trained in the cardinal principles of the Religious Society of Friends. These principles were the



JOSEPH SWAIN.

corner-stone of his philosophy of life. This Quaker faith is tolerant of others' convictions, avoids conventional sham, mixes in a peculiar way conservation and far-seeing liberalism. Quakers have believed in and practiced the theory of equal rights of men and women in the Society for two and a half centuries and for the same length of time have been consistently opposed to military strife. Some of its leaders, more than 200 years ago preached and practiced a socialism that today would seem radical. They are tolerant. They never proselyte. They believe in the good in man. Their one dictum is "Mind the Light."

The progenitors of Joseph Swain for many successive generations were Quakers. Joseph Swain was a Quaker. He was a farmer's son. Led by Professor Lewis Jones, then of Indianapolis, he entered Indiana University in 1879. He graduated in 1883. From 1883-85 he was an instructor in mathematics and biology in his Alma Mater. He married Frances M. Morgan in 1885. He studied in the University of Edinburgh, 1885-86. There he came under the influence of Chrystal and of Tait, whose friendship he enjoyed for many years.

He had an instinct for judging men. As an undergraduate he was the personal friend of many of the stalwarts of the Indiana University faculty. Many of his intimates among the undergraduates became leaders—great leaders—in their respective callings and professions and of great influence in the respective institutions with which they were later associated. The list is too long to record here. I may mention only one—the long, close-knitted friendship of Joseph Swain and David Starr Jordan.

He had an abiding interest in Science. He was an assistant to the United States Commissioner of Fisheries in 1884. Some of his earliest papers were published by the United States Fish Commission. On the other hand his innate administrative ability, his love of men, his ability to see the possibilities of a situation, his ability to see the necessity of and to secure the material needs for a research made him an administrator rather than a research man; an administrator who provided in very many instances the opportunity for others to delve into nature's secrets. He was able also to divine the relative importance of a proposed research. He had accumulated as the years went by many things about which he intended to know the truth when his administrative duties were over. It was a tragedy that lack of robust health deprived him of this opportunity.

He was professor of mathematics in Indiana University, 1886-91; professor of mathematics, Stanford University, 1891-93; President of Indiana University, 1893-1902, and President of Swarthmore College, 1902-21.

He played a large part in the affairs of the National Educational Association, being in succession, President of the section of Higher Education; President of the Council of the National Educational Association; and finally, President of the National Educational Association, 1913-14. This was a particularly constructive period of the N. E. A. The dignity of teaching as a profession was greatly appreciated during this epoch. The salaries and pensioning of teachers was a concern which

lay heavily on his heart and he played a dominating part in the establishment of the present pension system for public school teachers.

Swain's greatest contribution, in my judgment, was not that of an official but that of his personal influence. A few moments were sufficient to convert a culprit called to his office into a man who went out with a desire to try again. To the discouraged he pointed the way of life; to those who needed help he showed the way to self-reliance. With rare skill he transferred the misfit into his proper sphere. All this he did with a wisdom and tact of which he himself was entirely unconscious.

J. A. MILLER, Swarthmore College.

EMERSON BLANE WRIGHT.

LAPEL, INDIANA. SEPTEMBER 21, 1884.

INDIANAPOLIS, INDIANA. APRIL 17, 1928.

Emerson Blane Wright was born at Lapel, Indiana, September 21, 1884, and died at Indianapolis, Indiana, April 17, 1928.

He received his education in the rural schools of Hamilton County, at Lapel High School, and at Indiana University, graduating from the latter institution in 1913 with the degree of Bachelor of Arts and later taking the Master's degree there. He was a member of Phi Delta Kappa, honorary educational fraternity, of the Masonic Lodge, and of

EMERSON BLANE WRIGHT.

the Methodist Episcopal Church. In 1910 Mr. Wright was married to Miss Charlotte Passwater at Noblesville. Mrs. Wright, Maxine, their 15-year-old daughter, his mother, two sisters, and a brother survive him.

While a boy, living on the farm, Mr. Wright acquired a deep love for nature, which was manifest throughout his life. He began his teaching career in the rural schools of Hamilton County, later teaching in Lapel High School, where he himself had been a student. Mr. Wright also taught in the high schools at Noblesville, Bloomington, and Vincennes, and in the vocational department of Indiana University. At the time of his death he was a teacher in Arsenal Technical High School of Indianapolis, where he had taught for nine years. At Indiana University he majored in botany and did considerable work in drawing, in which art he excelled. Later he taught mechanical drawing for several years. While at Technical High School his old love for the out-of-doors led him to take up the teaching of botany.

It is as a teacher that Mr. Wright performed the greatest work of his life. He early became a Christian, and in the rôle of teacher he had a great longing to inspire in his students a desire for the high ideals to which he himself aspired. Many are the boys and girls whose lives have been deeply influenced by the sincere and sympathetic interest which Mr. Wright took in their success.

In his church life he always took an active part in Sunday School, Epworth League, and he attended other church services faithfully. In his civil life he was always active in everything that was for the community welfare.

During his last illness, which lasted several months, his most intense longing was to get back to his classes at Technical and to carry on with his life's work.

Besides his family he leaves a host of friends who will mourn his untimely death. By his death the Academy of Science has lost a loyal member, and we desire to record our high regard of his life that his family and friends may know our appreciation.

C. F. Cox, Indianapolis, Indiana.

FRANK CASPAR WAGNER.

ANN ARBOR, MICHIGAN. OCTOBER 5, 1864.

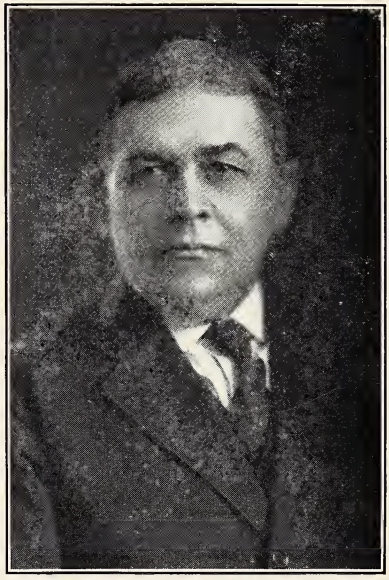
TERRE HAUTE, INDIANA. NOVEMBER 21, 1928.

The subject of this sketch, Frank Caspar Wagner, President of Rose Polytechnic Institute, lost his life on the afternoon of Wednesday, November 21, 1928. As he was leaving the grounds of the Institute his automobile was struck by an interurban car and he was instantly killed. Thus was brought to an untimely end the career of an unusually loveable man of noble character and of marked attainment in his chosen field.

He was born at Ann Arbor, Michigan, where he received his early education in the public schools of that city. At the remarkably early age of 19 he received in 1884 the degree of A. M. from the University of Michigan, and in 1885 he was granted the further degree of B. S. in Mechanical Engineering from that University. In 1924 the honorary degree of Sc. D. was conferred upon him by Rose Polytechnic Institute upon the occasion of his inauguration as President, and in 1927

the University of Michigan conferred upon him the honorary degree of Eng. D.

After his graduation in 1885 he entered the employ of the Thompson-Houston Electric Co. as erecting engineer, his work being principally located in Mexico City. He remained with this firm until he was called back to the University of Michigan in 1890 as Assistant Professor of Mechanical Engineering. In 1896 he came to Rose Polytechnic Institute as Associate Professor of Steam and Electrical Engineering. He held successively at that Institute the titles of Professor of Steam Engineering, of Mechanical and Electrical Engineering, and, when in 1921 the



FRANK CASPAR WAGNER.

two departments were separated, he was made Professor of Mechanical Engineering, which he retained until elected to the presidency of Rose Polytechnic Institute in 1923. These successive advances in title and rank are indicative of the degree of recognition of his talents as an engineer and an educator as well as of the esteem in which he was held by those connected with that Institute.

Aside from his work as an educator he was widely known as an engineer of note. His services as a consulting engineer were in almost constant demand and he had a wide practice, especially in the fields of steam engineering and heat transfer. He specialized particularly in patent suits and in patent investigations, in which latter field some of his most brilliant work has been done. These served to give him a national reputation and to make heavy demands upon his time and energy, but they brought a freshness of thought and a breadth of understanding to his classroom, which, in turn, made his instruction very

real to his students. During the World War his services as an engineer were utilized by his government, which called upon him for service as Engineer on the U. S. Fuel Administration for the State of Indiana.

He was most public spirited and gave freely of his time and his best efforts to aid every worthy cause of a civic nature, being especially interested in those appertaining to charitable undertakings. He was deeply religious and a believer in practical Christianity, which meant to him carrying it into his everyday doings; he lived his belief.

The range of his interests is indicated by the following: He was a Fellow of the American Association for the Advancement of Science; a member of the Society for the Promotion of Engineering Education; of the American Society of Mechanical Engineers; of the American Society of Electrical Engineers; of the Indiana Engineering Society, of which he was President, and of the Indiana Academy of Science. He was also a member of Tau Beta Pi. In addition he served upon the following local organizations engaged in civic work: The Chamber of Commerce of Terre Haute, the Smoke Abatement League, the Red Cross Society, and the Community Fund, of which he was President.

Such a man as that described above could not fail to leave a deep impression upon all with whom he came in contact. Possessed of a genial, kindly, and helpful nature, having deep convictions and a high sense of honor, he was beloved by his townsmen, by his faculty, and especially by his students, who will carry throughout their lives a keen appreciation of his kindliness, of his humanity, of his intellectual power, and of his greatness of soul.

"Large was his Soul; as large a soul as e'er
Submitted to inform a body here;
High as the place 'twas shortly in Heaven to have,
But low and humble as his grave;
So high that all the virtues there did come
As to the chiefest seat
Conspicuous, and great;
So low that for me too it made a room."

JOHN WHITE, Rose Polytechnic Institute.

PRESIDENT'S ADDRESS.

METALS AND THE MICROSCOPE.

E. G. MAHIN, University of Notre Dame.

The application of the microscope to the study of the internal structure of metals has given rise to what might almost be called a new science—certainly a new phase of science. While practically all of the work of this character has been done since the pioneering work of Sorby, in 1864, and of Osmond, in 1878, thus being comprised within a period of about sixty-five years, to date, the possibilities of the new methods now appear to be so important and far-reaching, and the results of such studies at the same time so useful and so fascinating that there is today no metallurgical industry that does not rely for its success, directly or indirectly, upon microscopic studies. And no one who has had even a glimpse of the structures that are revealed in metals by microscopic examination can fail to be interested and impressed.

The use of the microscope in this connection does not, at first thought, appear to be so revolutionary in character. For the microscope has been developed to a very high degree of refinement for a long time and it has been used in the study of materials of all sorts, and in a very wide variety of fields. But it is well to remember that ordinary methods, as familiar to every microscopist, will not apply at all in the case of metals. For the examination of biological structures, transparent minerals, etc., it is usually possible to prepare sections so thin that light will readily pass through them, thence into the optical system of the microscope and to the eye.

Such a method cannot well be applied to opaque metals. It is true that one or two of the very highly malleable metals—gold in particular—have been successfully beaten into exceedingly thin sheets, so that light will, to a certain extent, pass through these sheets. Gold, for example, has been beaten to a thickness of about $\frac{1}{180000}$ inch, and in this condition the sheets appear of green color by transmitted light.

There are at least three difficulties to be noticed in this connection if we are to attempt to apply this method to general metal examination: (1) The fact that these thin sheets appear green by transmitted light means that they are opaque to all of the other colors of the spectrum, all but a small fraction of sunlight, for instance, being stopped. (2) Only the highly malleable metals, like gold or platinum, could be beaten out to anything like this thinness. (3) And, what is more serious than either of these objections, we now know that the beating profoundly changes the original structure of the metal, so that even if a microscopic examination were possible it would tell us little or nothing

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

about the character of the metal as it was before beating. For this reason the value of the microscope, as a testing instrument in metallurgy, would be largely lost because one could neither study the changes of structure that accompany changes in physical properties nor form any intelligent idea as to causes of failure of metals to perform the service that was expected.

A moment's thought will convince anyone that by far the greater number of our visual observations, in general, are made by means of *reflected*, rather than transmitted, light, simply because most of the objects we see are opaque rather than transparent. What we ordinarily see is the surface of objects and we judge color, size, contour and surface outlines by means of light that has been reflected from the object to the eye. And yet it might seem, at first, almost hopeless to expect to determine anything regarding the internal structure of metals, merely by the examination of what we ordinarily see as the form of the surface of a piece of metal. This is because the surface is always so changed by wear, corrosion, oxidation or intentional modification that it does not truly represent the mass of metal underneath.

The method developed by Sorby and Osmond, and very extensively applied since their original work, was to cut through the metal and then to prepare the section so exposed by a process of progressive grinding and polishing, a brilliant and perfectly smooth surface finally being obtained. Even this would not serve for microscopic examination in most cases, simply because all that one could see, even with the aid of high magnification, would be a brilliant—usually nearly white—surface. But if this surface is dipped into a solution of some suitable reagent, which possesses the ability to attack the metal unevenly, most of the metals and alloys will be found to have developed a very remarkable—and sometimes a very beautiful—structure when viewed through the lenses of a good microscope. The development of such a structure is due to the fact that the metal is not a single, homogeneous substance. Most of the alloys consist of at least two crystalline materials and even the pure metals are found to have a structure made up of separate grains, the boundaries of which are attacked more than are the grains themselves. In the case of the alloys it nearly always happens that some of the crystals are attacked more vigorously than others, so that a relief effect is produced and the outlines of the different constituents are thus made visible.

This method of procedure opened up an extremely interesting and useful field for scientific investigation and observation, and numbers of metallurgists have followed the lead of the earlier investigators, so that we now have available a large amount of information concerning the internal structure and the properties of most of the metals and their alloys. In fact this work has become so extensive and so important that the new field has been given a name. We now speak of the microscopic study of metals and alloys as the science of "Metallography." And it is of the methods used in such study and of some of the results of the application of these methods that this discussion will treat.

Metals as Crystalline Aggregates. In the first place let us say at once that, so far as we know of them, every metal in existence is essentially crystalline in nature. This fact is not necessarily an obvious one, because ordinary experience with such soft metals as lead, or with such alloys as plumber's solder or aluminium, would lead one naturally to conclude that they are not crystalline. But this is because we are in the habit of associating *brittleness* with crystalline structure, the crystalline minerals or the crystalline compounds found in the chemical labora-

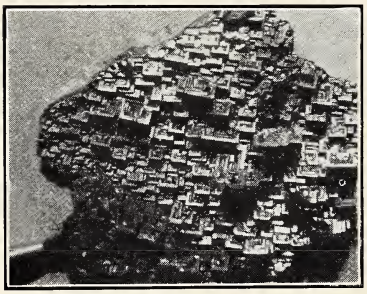


Fig. 1—Bismuth crystals grown in free space. x1.

Fig. 2—Surface of ferrosilicon. Skeleton of skin first frozen. x¼.

Fig. 3—"Galvanized" iron. x1.

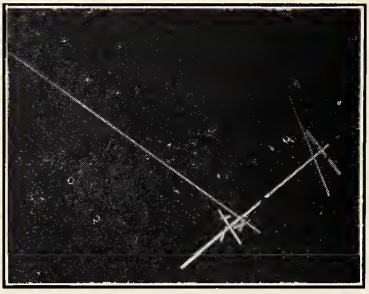


Fig. 4—Cuprous oxide (cuprite) crystals from a druse of copper nugget. x130.

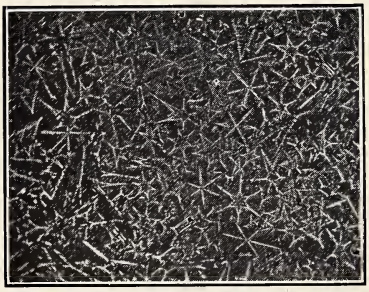


Fig. 5—Epsilon copper-tin crystals from lower end of cast Babbitt metal. x100.

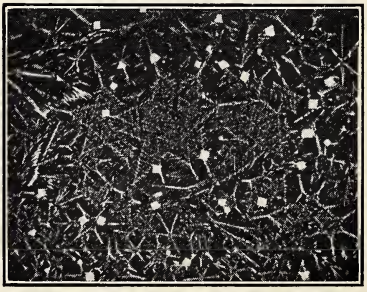


Fig. 6—Same as figure 5 but with gamma tin-antimony crystals. From top of cast. x100.

tory exhibiting this characteristic almost without exception. Such a conclusion would be decidedly erroneous; and it might be noticed also that glass is a common example of a transparent and brittle substance which is not at all crystalline.

The crystals of metals are not always perfect in *outline* because of the restrictions under which they have formed, but even then the mass is crystalline in structure. It is only when crystallization of one constituent of an alloy occurs while the remainder of the material is still liquid, or upon the surface of a metal or alloy which has either cooled quietly from the liquid state, or which has condensed from the vapor state, that unmistakably crystalline outlines are seen. Some of these are illustrated by the accompanying reproductions of photographs.

Figure 1 is from a photograph of a beautiful specimen of bismuth, cooled upon the lining of the ladle in which it had been melted, and from which most of the metal had been poured. Figure 2 is the upper surface of a melted and cooled ferrosilicon, an alloy of iron and silicon. Figure 3 is the surface of ordinary "galvanized" iron, so familiar to everyone. This is simply a zinc-coated iron, prepared by dipping clean sheets of iron into melted zinc, the latter crystallizing as it cools. Some very beautiful figures may often be seen upon such material if it is examined while new and before the surface has become dirty or worn or oxidized. These figures suggest the appearance of a window pane on a frosty winter morning; and the ice crystals there noticed have, in fact, grown over the glass by a process quite similar to that of the zinc crystals on the iron.

All of these are examples of crystal formation without interference of solid matter. As another example of such crystallization in free space, although not of a single metal or alloy, in figure 4 we have a photomicrograph of a group of nearly perfect crystals of copper oxide, found grown upon the walls of a small interior cavity of a piece of native copper. This particular nugget of copper weighed nearly 27 pounds. It was brought down into northern Indiana, probably from the Lake Superior district, as glacial drift, ages ago. And in a cavity not more than a half inch in diameter these beautiful crystals had been hiding, perfectly protected from mechanical injury or atmospheric corrosion, to be revealed by the hand of man several thousand centuries later. The tombs of the Pharaohs can give us nothing more wonderful. For here has Nature herself built a perfect structure of the atoms of copper and oxygen laid upon each other as no block of brick or stone can be laid by man, and as no man-made tool may fashion—each atom itself an invisible universe of whirling electrons but each eternally keeping its own proper position in the crystal.

Suppose that a more careful examination is now made of a piece of soft bearing metal, an alloy of tin, copper and antimony known as Babbitt metal. Nearly everyone is more or less familiar with this alloy or with an alloy somewhat similar to it in composition, as used in many bearings of automobiles and other machinery, and it is well known that such alloys are easily melted and poured into forms.

If a piece of genuine Babbitt metal is melted in a clay or iron crucible (at a temperature of about 400° C.) and then poured into a mould and allowed to cool slowly, one will have what corresponds to a cast bearing. Good cast bearings should be allowed to cool more rapidly, but in the present instance we should have this one cool slowly.

The cooled ingot of solid alloy is now to be cut so as to expose sections, the first one near the top and then one near the bottom. If these sections are polished, beginning with coarse emery cloth and following this, in turn, with finer emery cloth, wet emery on canvas, wet tripoli and wet rouge, finishing finally with an extremely fine abrasive, such as wet alumina (aluminium oxide), the polished sections being then immersed for a short time in a dilute solution of nitric acid in alcohol, and finally washed, dried and placed in the proper position in a microscope, one may observe a beautiful starry system of bright crystals in a darker sky of metal mass.

The section taken near the bottom of the ingot would appear something like the photomicrograph of figure 5. In this picture the dark background is nearly pure tin, while the starry clusters of crystals are composed of a sort of complex of tin and copper, designated by the metallographist as *epsilon* tin-copper—Greek letters being used to designate the various members in alloys.

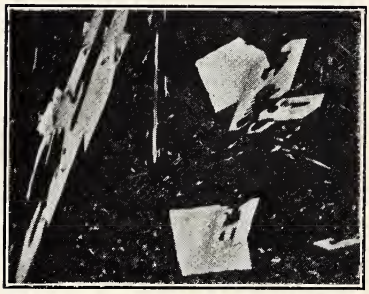


Fig. 7—Crystals in Babbitt metal. x500.

Fig. 8—Lead grains in cast lead. x150.

The picture of the section through the upper portion of the ingot, as shown in figure 6, may now be compared with this. In addition to the crystals already noticed we have here a new one of apparently cubical form. This is a complex known as *gamma* tin-antimony. Both of these crystals are very hard. And the thorough distribution of these hard particles throughout the softer and more plastic mass of more nearly pure tin is thought to be largely responsible for the excellent behavior of this alloy as an "anti-friction" bearing metal. The hard crystals by themselves would be brittle, and they would also be liable to cut and ruin a steel journal running in such a bearing, while tin alone would be too soft and yielding to be of much use. But in a conglomerate of this kind the hard crystals take the wear, while the softer matrix allows them to adjust themselves to minute irregularities of the moving journal surface, the bearing suffering no noticeable distortion.

This being true it is easy to see that a good bearing must have its hard crystals small and evenly distributed.

The formations of stars and triangles of figures 5 and 6 are clusters rather than single crystals. Figure 7 shows some of these at higher magnification. The *gamma* crystals are nearly perfect cubes, the well formed outlines being made possible because the crystals form while the principal portion of the alloy is still liquid.

Usefulness of Metals. If the average individual were asked to state, without taking much time for reflection, what is the most important and useful property of metals, in general, he might possibly mention their power to conduct electricity as of very high importance or their ability to take a fine polish, so that they may become ornamental parts of various useful articles—or even of their relative permanence when exposed to various influences that would promote decay of non-metallic things. One might think of these or of various other characteristics—but the chances are more than even that he would say that metals are of the greatest usefulness to man because of their exceptional *strength.*

And this would be quite right. All metals are conductors of electricity and some are excellent ones, thus making possible a bewildering variety of interesting and useful electrical appliances as well as serving as parts of machines for power production and utilization in modern industries. Some metals resist to a high degree the corrosive action of air and acids. All may be made to combine with certain other chemical substances in such a way as to produce many salts, oxides and other compounds, useful and nearly indispensable in our modern life. But, after all, the characteristic which separates metals, as a class, from most of the other materials which we know, and which gives them an outstanding importance to us, more fundamental and necessary than any of the properties mentioned above, is that of being able to resist pulling, bending, twisting, abrasion or compression without changing form or breaking.

This is the characteristic which makes possible all of our modern machinery of every description. If a metal could be pulled apart as easily as a stick of wood; or bent or twisted as a piece of rubber; or cut or penetrated by a point, as a lump of wax—or broken by a blow, as a mass of stone—modern life would be a very different matter from what it is, for the great bulk of modern industry and commerce, depending as it does to so great an extent upon the use of metals, would not exist. As to what would be the effect of this upon the ideals and ideas of our present civilization one may only speculate, and we may leave this to the philosophers. But certainly life would be fundamentally different from what it is; perhaps not as life in the Stone Age, for the world does change—but at least in a modified or somewhat improved Stone Age.

Pure Metals Are Not Strong. There is another thought that must be noticed in this connection. In the search of all known metals for a material that will meet our present needs in the matter of strength, *no single metal is found to serve.* Many metals are strong and at the

same time free from brittleness, as compared with most other materials of construction, but none of them will meet the needs and requirements of modern industry.

One may notice a few examples. Tungsten, formed into a wire or filament, provides a means for converting electrical energy into light energy, and with less waste in the form of heat than would be the case with most other metals, and so the incandescent light bulb is a universal convenience, and even necessity, today. But that filament is so weak and fragile that a very light blow upon the cold bulb will shatter the filament.

Platinum is a highly prized metal on account of its high fusing temperature, its remarkable resistance to corrosion by acids and other chemicals, and its ability (when in a fine state of division) to promote certain chemical reactions by "catalysis," as in the manufacture of sulphuric acid. (We may leave entirely out of consideration its appeal to the vanity of man, who—because of its present extraordinarily high cost—must have platinum in his teeth, his watch and his fianceé's engagement ring, thus crippling the chemical industries.) But platinum is so soft that it may easily be scratched or cut by a knife; so weak that very large masses would be required to withstand any important stresses. Even the platinum crucible of the chemist's laboratory has to be handled with great care if it is not to be ruined by bending or crushing.

Gold has long been used in jewelry and other ornamental articles and in coinage because of its beauty and because it is not easily oxidized or corroded. But pure gold is so soft that if jewelry or coinage were to be made of it such articles would soon wear out or become bent or scratched. Copper or other metals are always alloyed with gold in order to change this condition.

Copper is useful especially because of its high degree of conductivity for electricity. But pure copper also is quite soft and weak, and if it is to be used for other purposes in the pure state this relative weakness has to be compensated by increase of mass.

Even iron, one of the strongest of our common metals, in the pure and unalloyed condition will not do for much of our modern demands. Of course nearly pure iron is used in relatively small quantities in sheet form for tubular culverts and silos, roofing or rain gutters on buildings, and for other such purposes where a relatively high degree of resistance to weather conditions is provided by its relative purity.

Alloys Are Stronger Than the Metals of Which They Are Composed. One might go on almost indefinitely with these examples, recounting the striking characteristics and important uses of each metal. But always we should come back to the original proposition: that if a metal is to be made particularly strong something has to be done to it. Various treatments will improve the strength, but first of all it is well to notice this extremely interesting fact: *If two or more metals are alloyed with each other by melting together the solid alloy is always harder and stronger than would be expected from the general rule of averages.*

This is the first part of the principle of strengthening by the addition of another element. The second part, an extension of the first, is this: *It is usually true that the more easily one metal dissolves in (alloys with) another the less is its strengthening effect, and conversely.*

Other Indications of Crystal Structure of Metals. In the preceding discussion there have been shown some reproductions of photomicrographs and of ordinary photographs as indications of the crystalline nature of certain metals and alloys. But we have now to pass to others where the case is not so obvious. Indeed it might be said at once that in the majority of instances the microscopic examination of a section of the metal would not furnish very convincing evidence of crystal structure.

As an example of this, figure 8 represents a polished and etched section of a piece of lead. These rounded and irregular grains are not at all crystalline in appearance. Figure 9 represents a microsection of nearly pure iron—"ingot iron" it is called—and it is one of our best commercial forms of iron. Here again the irregularly formed "grains" of iron make up the entire mass. Figure 10 represents a piece of type metal, an alloy of lead and antimony. True, the bright network gives a certain suggestion of crystallinity; and yet one would be rather venturesome to predict, without further evidence, that the cell formation would prove to be of true crystals.

A great many other examples might be cited, illustrating by photomicrographs of metals or alloys that have a granular, rather than an obviously crystalline, appearance. But these are enough to lead to this point, already noticed, that *usually it is in only those cases where crystals may complete their formation in contact with liquid or free space that their outlines are obviously crystalline in form.*

Crystallinity Is Not Merely a Question of Outline. The terms "crystalline structure" and "crystalline outline" have been used in this discussion as though they represented two different ideas. And so they do. Perhaps the outline has, until recently, been regarded as the most striking feature of crystals (at least aside from certain important optical properties), but that was because we lacked evidence as to the nature of the crystal body itself. But there is no inconsistency in this. If one were to take a well formed crystal, say of alum, and grind off the external portions to form a rounded mass, the nature of what was left would not be changed any more than the grain of a piece of wood would be changed by turning it into a croquet ball.

Crystals Within Crystals. Figure 11 represents the structure of a high-carbon steel (1.1 per cent carbon). Such a steel is quite hard and strong, even without sudden cooling from high temperatures. This is because of the presence of a very hard carbide of iron, here visible as a bright network and as brilliant crystals shooting across the meshes of the network. But if the steel is examined with the aid of lenses of higher power the enmeshed grains are found also to possess a definite structure of alternating strips of dark and light. This structure is shown in figure 12.

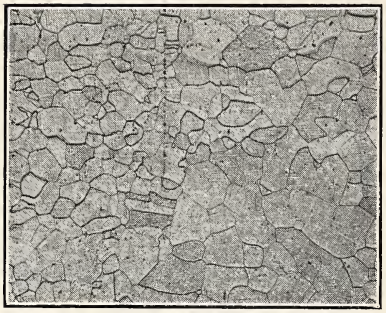


Fig. 9—Ingot iron. x100.

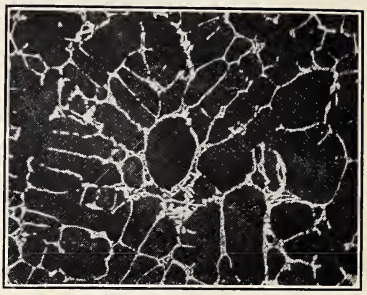


Fig. 10—Type metal—alloy of lead and antimony. x50.

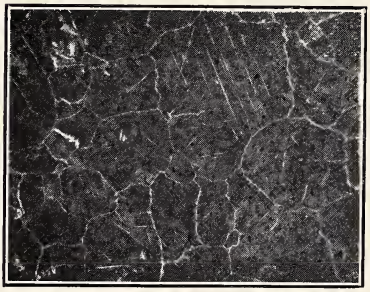


Fig. 11—High carbon steel. x100.

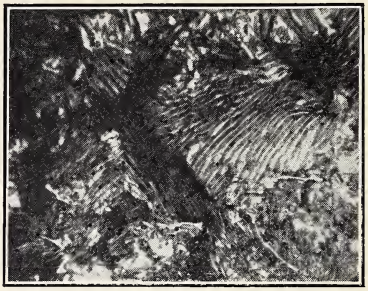


Fig. 12—Pearlite in steel. x750.

Figure 13 represents a section of a cast steel; that is, of a steel which has cooled slowly and without disturbance from the temperature of the liquid to that of the solid condition. Here also the arrangement of dark and light plates rather irresistibly suggests a crystal structure, although it is definitely known that this appearance is due to a crystal which has existed just after solidification and which has bequeathed its "image" to its descendants.

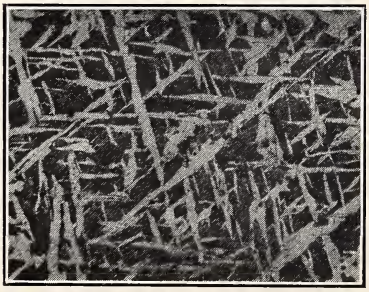


Fig. 13—Cast steel. x50.

Fig. 14—Slip bands in strained ingot iron. x130.

And so, here and there, it is possible to find these polyhedral (many-sided) grains which exhibit traces of a former or of a present crystalline form. Nevertheless there are too many cases where no such traces are apparent to make it possible to generalize upon the basis of such evidence alone. Consider then what happens when a granular metal, such as iron, is deformed by hammering, stretching, bending or any other means.

A piece of ingot iron similar to that represented in figure 9 was first photographed, as has been seen, then it was placed in a heavy vise and squeezed until its external form was permanently changed. This, of course, means that the iron was strained. Figure 14 shows what has been done to the iron. Each grain is crossed by one, two or three sets of fine dark lines, whose directions usually change at the grain boundary. This indicates rather unmistakably that there is some sort of order in the manner of assemblage of the ultimate particles composing the grain itself, so that when the metal was strained there was a disturbance concentrated upon certain planes—remembering again that we are seeing only one section of the metal and that these dark lines probably represent planes in section.

The X-ray in Metallurgy. It has long been known that ordinary visible light consists of pulsations or waves, in some all pervading medium, which the physicist calls the ether—that it is refracted or bent when passing from one transparent substance to another of different density, and that different colors are refracted to different degrees, so that when "white" light, for example (white light is merely a combination of all colors), is passed through a glass prism it is spread out into a strip of beautiful rainbow hues, these being the components of the original light.

Fig. 15—Conventional representation of wave length.

It is known also that the extent of refraction of a wave depends, among other things, upon its wave length, which is the distance between like phases of the wave. Thus, if we follow the conventional method for representing waves the wave length would be the distance from a to a', b to b', c to c', etc., of the line in figure 15. Violet light is of relatively short waves and red of long; the other colors lie between these in wave length.

But the light to which the human eye is sensitive covers only a very small portion of the enormous range of other radiations, many of which have been discovered within the few years just past.

Units of Measurement. In order to have some tangible method for designating the length of such radiations or waves it is necessary to use a unit of measurement much smaller than any that are employed for ordinary measurements for everyday use. For example, if the inch were to be taken as the unit there would have to be so many zeros after the decimal points that one would tire of writing and counting them.

For very short distances, such units as the *micron* (symbol μ), the millimicron ($\mu\mu$), and the Ångström (Å) are used. The first is one-thousandth of a millimeter, the second one-millionth of a millimeter and the last one ten-millionth of a millimeter—or one-tenth of a millimicron. These may be related to the inch by remembering that about 25 millimeters are equivalent to an inch. If all of the figures given above are divided by 25, the following relations are found:

1μ = 0.001 mm = (about) 0.00004 inch
$1\mu\mu$ = 0.000001 mm = 0.00000004 inch
1Å = 0.0000001 mm = 0.000000004 inch

Known waves that are very much shorter than those of visible light are the ultra-violet rays, the X-rays and the *gamma* rays of radium. Known longer waves are the infra-red or heat rays and the Hertzian waves used in radio transmission. The latter are so much longer that we drop the use of the smaller units and express the wave lengths in meters—or we might use the kilometer or the mile as a unit, although no one does this.

The following table gives the range of wave lengths of such radiations as have been mentioned. It will be noticed that there are still several unexplored gaps and it may well be that radiations will be discovered which will fit into these gaps—perhaps radiations that will prove to be as remarkable and useful as any that we now know.

TABLE I. Wave lengths of some known radiations.

Designations	Range, Ångström units	Range, millimeters
Gamma-rays	0.01 to 0.1	0.000000001 to 0.00000001
X-rays	0.1 to 10	0.00000001 to 0.000001
Ultra-violet	100 to 3800	0.00001 to 0.00038
Visible light	3800 to 7800	0.00038 to 0.00078
Infra-red	7800 to 313000	0.00078 to 0.00313
Hertzian	.....	2 mm to 10000 meters

It is a well known fact that X-rays will pass through a great many materials that are opaque to ordinary light and it is because of this property of such radiations that X-rays have proved to be so useful in surgery and medicine as well as in industry. We do not actually see the objects that are revealed by X-ray examination, for the human eye is not responsive to the effects of such rays. But we do see the effect of an X-ray shadow upon a special screen which becomes fluorescent where the rays strike it. Also we may see a photograph, for X-rays affect the photographic film and this makes possible a permanent record of the desired form.

If a narrow beam of such short waves as X-rays is made to pass into a crystal—which may be either an ordinary "transparent" crystal or one of an "opaque" metal—many of them will pass on through or be absorbed, but a minute amount of the radiant energy will be reflected from the atoms or molecules composing the crystal mass. Under ordinary conditions the reflection will be very faint, but if the angle of

striking is just right the radiation is reflected in separate beams of characteristic angles. A print made from a negative film recording such reflections is shown in figure 16. Here the rounded bright spot at the central point represents the position of the main portion of the original unreflected beam, while the bright spots are from the portions that are bent out of position by the reflecting atom planes of the crystal.

If a powder of such a crystal or a small mass of metal containing crystals whose axes are variously directed is used instead of a perfect crystal these separate beams form circular bands, centered about the main unreflected beam. Figure 17 shows such an effect.

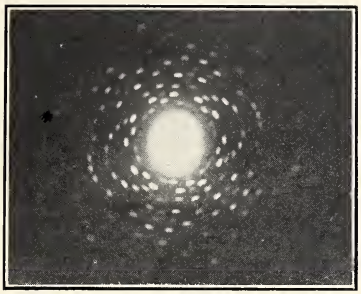


Fig. 16—Laue X-ray spectrogram of potassium nitrate. Courtesy of Professor E. D. O'Connell.

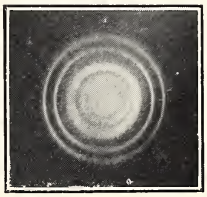


Fig. 17—Spectrum of aluminium crystal to powdered form. (After General Electric Co.)

The fact that is of the highest importance here is that the *intensity* and *spacing* of these reflected beams bear a very definite mathematical relation to the *arrangement* of the atoms within the crystal and to the *distances* between atom centers.

Without going into details of construction of the apparatus or of the calculations themselves we may find it interesting and profitable to note several conclusions that have been reached as a result of many researches conducted with X-rays:

1. In any crystalline material, whether of an element or a chemical compound, the constituent atoms are assembled in a definite pattern in space instead of in the non-orderly plan of amorphous substances. ("Amorphous" means, literally, *without form.*)

2. Nearly all of the metals crystallize in the cubic system—a system in which the three axes of symmetrical atom grouping are equal in length and perpendicular to each other.

3. The "space lattice" (the pattern representing the arrangement of the atoms in three-dimensional space) of most metals is comparatively simple. The most common two are the *face-centered* and the *body-centered* cubic lattices.

The Crystal Space Lattice. In order to visualize the lattices, imagine that we have a stack of small cubical blocks. Arrange these in an orderly, close-packed fashion and suppose that an atom of some element (say the sodium and chlorine atoms of common salt—sodium

chloride) is situated at each point where the corners of eight blocks come together. This, of course, means that each cubical block has an atom at each of its eight corners, although each atom is a corner atom shared by eight blocks.

If now the blocks could somehow be caused to vanish, leaving the atoms suspended in space, we should then have the *simple cubic* space lattice, which might be represented diagrammatically as in figure 18,

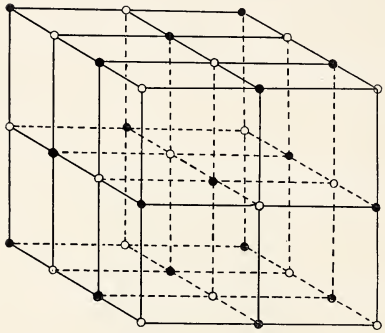


Fig. 18—Simple cubic space lattice of sodium chloride.

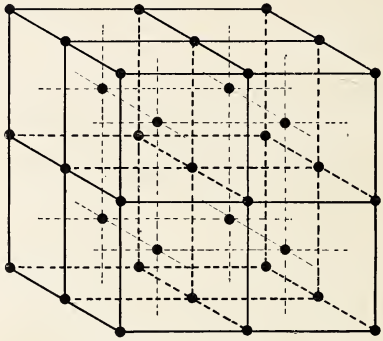


Fig. 19—Body-centered cubic space lattice.

where the dark circles represent the positions of atoms of sodium and the open circles those of chlorine of sodium chloride. The straight lines of this diagram are used merely to assist in visualizing the space relations of the atoms within the crystal and to indicate the probable directions of the principal inter-atomic attractions.

Going back to the pile of blocks suppose, first, that iron atoms replace all of the corner atoms of sodium and chlorine, and, second, that there is an additional atom of iron at the center of each cubical block. Again let the blocks vanish, leaving the metal atoms exactly as placed. The result now is the simple *body-centered cubic* space lattice of ordinary iron (*alpha*-iron). This is depicted in figure 19, in which

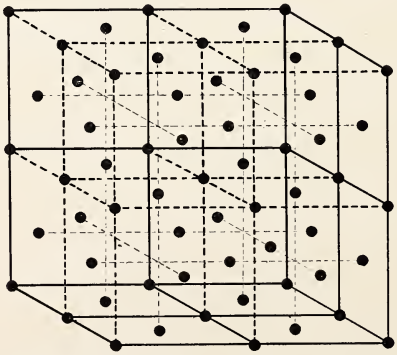


Fig. 20—Face-centered cubic space lattice.

dotted lines have been added to indicate the positions of the centered atoms, all of the atoms now being of the same element—iron. Once more, suppose that the centered atoms are absent but that, in addition to the corner atoms, one additional atom is at the center of each *face* of a given block. Of course this atom will be shared by two adjacent blocks, just as each corner atom is common to eight blocks. If now the blocks are again caused to vanish we shall have the simple *face-centered cubic* lattice, such as exists in iron when it is heated to any temperature between 900° and 1425° C., when it is known as *gamma*-iron. This space lattice is represented in figure 20.

A metal which, like iron, can thus exist in two or more different crystal forms is said to be "allotropic." Iron is one of the few allotropic metals, and this one fundamental fact is responsible, in a large degree, for the extreme usefulness of this metal in our industrial life because it makes possible the thermal treatment of steel, thus fitting it for such a great variety of uses.

How Many Atoms are in a Crystal? Any representation such as those of figures 18, 19 and 20 must be regarded as extremely inadequate to show the enormous numbers of atoms involved in the structure of a single crystal, even when the crystal is of only microscopic dimensions. For we must remember that the lattice extends in the three dimensions to the crystal boundaries and, further, that the atoms are very small and very close together, as measured by ordinary standards. While the inter-atomic distances vary somewhat with different metals, and with a single metal at different temperatures or in different allotropes, it is quite possible to form some conception of these distances by considering iron itself. It has been shown by Westgren and others that the straight side of a single cubic unit (corresponding to the straight side of the single block of the imaginary pile) of *alpha*-iron is about 2.87 Å, and of *gamma*-iron 3.61 Å. Reference to the definition of the Ångstrom unit will show that these dimensions, in terms of ordinary units, are about 0.000000011 inch and 0.000000014 inch, respectively.

The maximum diameter of the crystal grains of a good quality of steel is about 0.01 inch. Although the grains are not cubical in form, we may take some liberties with the facts and imagine them so. In this single small crystal we shall then have approximately one million lattice units, arranged regularly on a given straight line in each of the three space dimensions. This will give 1,000,000,000,000,000,000 (one quintillion) lattice units in the crystal, and this of course means the same number of atoms for the cubic unit corners. Practically speaking, we have the same number of atoms for the cube centers, for we have only to draw the lines of figure 19 somewhat differently to prove that each body-centered atom is a corner atom for eight units of a different system. The total number of atoms in this *alpha*-iron crystal is then about 2,000,000,000,000,000,000.

Of course these figures are only approximate and they are of such enormous numerical value that the mind can form little conception of their true magnitude. But a little thought given to these matters should at least cause us to appreciate the wonderful technique that has made such measurements possible. And it should bring home to us anew this

amazing truth—that the eternal *order* of the universe goes not only to the magnificent and incomprehensible distances measured by the astronomer, but also in the opposite direction to the infinitesimal structures of the physicist and the chemist.

While we are about it we might as well indulge in a bit of philosophy. We speak of going out in one direction to the "immense" sizes and distances—those of the astronomer, who deals with stars and interstellar spaces—and back in the other direction to the "small" of electrons, of atoms and of interatomic distances. But, after all, that is only because we happen to be situated "between" these conceptions. The things and sizes and distances that are easily experienced and comprehended by the unaided human senses—these we regard as normal. Very much greater or less than these we regard with a certain degree of awe.

But this absolute order of structure and composition and natural law which science is uncovering as we plod, step by step, through its maze—this order is all-pervading and eternal. This law of structure and of operation of physical and chemical forces is the very foundation of the universe. If such figures as those given above can do nothing else for us they can at least help us to realize that numbers and sizes and distances are mostly relative in their significance. Man may come to some sort of understanding of both the infinite and the infinitesimal, these terms being themselves but mathematical conceptions. But he has yet a long way to go as he strives, individual by individual, generation by generation, to push back the boundary of the unknown—to lift the dark curtain which veils the inscrutable. There is no inscrutable if we are to speak in terms of unlimited time for effort. What time shall be permitted the human race for that effort and how far we shall go in the search for other fragments of the complete truth we do not know, and we should be rash to attempt to predict. But if the man of science cannot find, in these reflections, inspiration for a continuation of his efforts he is not likely to find it elsewhere. Certainly not in the mere search for bread and butter to feed his stomach.

Straining. What happens to a piece of metal when it is strained? If the muscles or ligaments of the human body become accidentally overstressed the result is an injury, which requires time for repair by natural physiological processes. If a piece of wood is bent or twisted or compressed so far that its form is permanently changed, as a general rule it will have been weakened. For such treatment actually begins the process of tearing apart the fibers or cells composing the biological structure. It may, therefore, be somewhat surprising to learn that exactly the opposite is true of a metal. But this is indeed a correct statement of the case if it be understood that the straining is not to be carried too far.

Straining Without Undue Heating Strengthens a Metal. If a bar of iron or brass or of any other non-brittle metal or alloy is rolled (without previous heating) into a sheet, drawn into a wire or stretched, hammered, squeezed, twisted or otherwise deformed, and if its hardness, tensile strength or elastic limit are tested, both before and after such

drastic treatment, it will be found that the numerical values expressing these qualities have been raised, sometimes to a remarkable degree. Thus, a piece of commercially pure iron may have its tensile strength raised from about 50,000 pounds to about 125,000 pounds per square inch by cold rolling or by drawing it through dies of decreasing size, as is done in the process of wire making. At the same time the hardness is very much increased. Similar changes are noticed in copper, brass and most other metals and alloys, providing that they are not too brittle to permit such treatment without fracture.

Such plastic deformation of metals within ordinary temperature ranges is known as "cold work," as distinguished from "hot work," which is similar deformation at higher temperatures.

The attempt to understand why cold working strengthens a metal has provoked many conjectures and it has been the inspiration for many researches. Without going into a historical development of the various theories it may be well to summarize the views most favored at present.

Attention has been called to the series of criss-cross lines which develop upon the polished section of a metal when the piece is strained. It is also to be noted that the irregular crystalline grains composing the mass of a metal are distorted by cold work, their new form depending upon the kind of deformation which the piece, as a whole, has suffered. Thus, if a billet is rolled into a sheet the grains are flattened. If a rod is drawn into a wire the grains are stretched into longer ones, their longest diameter being in the axis of the wire. Such an effect is illustrated in figure 21, which is a photomicrograph of a piece of a high-pressure gas cylinder made from cold-rolled steel of low carbon content. Figures 22 and 23 show similar effects of cold working of medium-carbon steels.

Fig. 21—Cold rolled low-carbon steel. x100.

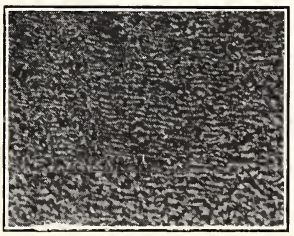


Fig. 22—Cold rolled steel. x100.

Going back for a moment to the atom lattice of the metal crystal we may illustrate what probably happens to the metal under severe stress by figures 24, 25, and 26. In these drawings an attempt has been made to simplify the matter by indicating atom positions merely by intersections of parallel lines, one set perpendicular to the other, thus indicating a cross-section of a metal having a simple cubic lattice.

Suppose that the original crystal, represented by figure 24, has a shearing stress applied, as indicated by the arrows of figure 25. If

this stress be not too great the crystal is distorted slightly, and if the stress is then removed the crystal will resume its original form. It has then been stressed within the elastic limit. While temporarily each individual atom has altered its position relative to the others, the essential inter-atomic relations have not been seriously disturbed. The condition of the lattice while under such stress is conveniently represented by figure 25.

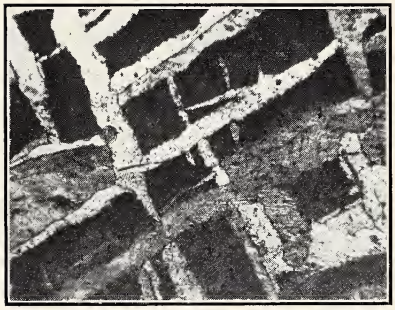


Fig. 23—Cold worked, medium carbon steel. x100.

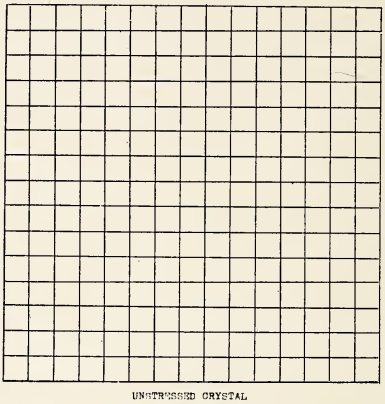


Fig. 24—Conventional representation of a section of an unstressed crystal.

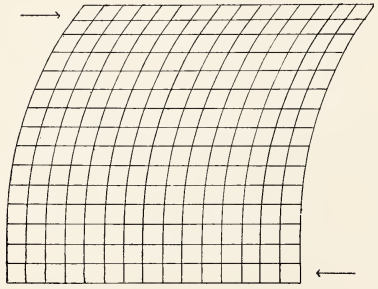


Fig. 25—Conventional representation of a section of a crystal, stressed within the elastic limit.

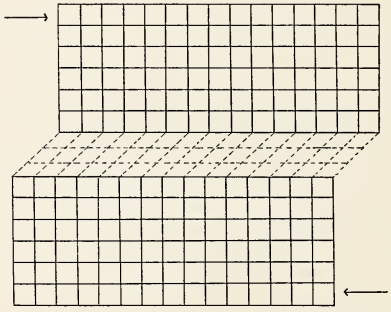


Fig. 26—Conventional representation of a section of a strained crystal.

If the stress is again applied and continuously increased, a value will presently be reached where the crystal has been deformed to a point where it will not return to its original form when the stress is removed. It has then passed the elastic limit and the metal is permanently strained. In the same conventional way the strained crystal may be represented by figure 26, where the main portion of the crystal has maintained its integrity of form but along certain atom planes a sliding or gliding has occurred, somewhat as a neatly piled pack of playing cards will slide along certain cards, if one pushes in a horizontal direction against the top of the pile. The planes along which such disturbance has taken

place are called "slip planes," and the dark lines visible in figure 14, each including enormous numbers of these slip planes grouped together, are known as "slip bands."

Just what has occurred in the regions of the slip bands we do not know for certain and we cannot represent the change by the method used in figure 26. It has been supposed that the regular lattice has been torn down along the slip planes so that the metal in these regions is no longer definitely crystalline but rather amorphous. Also it has been thought that an increased amount of amorphous metal has been formed where slip planes intersect grain boundaries, themselves probably amorphous. And because of evidence that amorphous metal is harder and stronger than crystalline metal this has been held to account, at least in part, for the improved qualities.

It has, so far, proved to be impossible experimentally to demonstrate the existence of amorphous metal, either at grain boundaries or along slip planes, so that these theories remain merely as possible explanations, but at least suggestive and interesting. What we do know is that some rather profound disturbance has taken place within the crystal lattice, *but that the atoms have not been permanently torn apart,* as is the case when a real fracture is produced. On the contrary they continue to offer resistance to repeated deformation and the metal has been, on the whole, "stiffened up." Cold working, therefore, remains an extremely valuable method for increasing the physical strength of metals. "Cold-drawn wire," "cold-rolled sheet," and similar terms have then a peculiar significance.

Solutions. Just a remark or two concerning the ordinary use of the term "solution." People usually apply this term only to ordinary liquids. We speak of a solution of sugar or salt or soda in water, of iodine in alcohol, and so on, always keeping in mind the *liquid* character of the mixture. Lemonade is then a solution of sugar, citric acid and certain flavors in water; varnish is a solution of certain resins and oils in turpentine or alcohol. But after all, at least to the chemist, the physicist or the metallurgist, a solution is but an extremely intimate mixture of the molecules or atoms of the two or more substances which are dissolved in each other. And solutions may be either liquids, solids or gases. The atmosphere is a gaseous solution, principally of oxygen and nitrogen. And all alloys are (at least within certain temperature ranges) liquid or solid solutions of their component metals.

The idea may be extended a bit farther. We have seen that crystals are orderly structures of atoms, built together in a perfectly definite pattern. If now to a pure metal we add a second metal (or even one of several non-metals) and heat to a temperature where solution may take place (this is the melting temperature in some cases, in others not) solution occurs by the process of atoms of the dissolving element—the "solute"—either crowding solvent atoms out of their places in the crystal lattice and taking these places themselves or crowding into spaces between the solvent atoms.

This means that the interlopers try to assume the functions of the former residents, usurping their places and reaching out their combining

forces to neighboring natives. "Trying" is the proper word, for no atom of the foreign element is exactly like the one which has been displaced. It is not of exactly the same size nor has it the same characteristics in other respects. The result is that, here and there, the atom lattice of the crystal is distorted. Atom planes are no longer true planes.

If mechanical analogies are preferred suppose that a mason is constructing a house, using carefully sized bricks of specified dimensions. His courses of bricks are neatly laid, forming beautifully straight, horizontal rows. But his bricks are running short. He lacks a few, cannot obtain the right kind in a hurry but finds that others are available, almost like the proper kind but not quite. They are slightly larger or slightly smaller or certain dimensions—length, width or thickness—are slightly different. A few of these odd ones are worked in, here and there. Not in one place, of course, for that would be too obvious. With this scattering of odd formed units the result is not, perhaps, *too* obvious, but a critical eye will now see that the rows are no longer regular and straight. They are slightly distorted, just as the crystal space lattice is distorted by the entrance of foreign atoms that will not exactly fit.

Or recall the analogy of the smooth pile of playing cards and suppose that, instead of these being high-grade cards, they are of cheap pasteboard, the fibers containing a good many of those small lumps so often found in low-grade paper. These lumps are like the foreign atoms taking the places of solvent atoms in the space lattice. To use one more illustration, suppose that the cards are of the smooth variety but that small particles of some rough solid have been scattered here and there between the cards. These solid particles will now represent dissolved atoms crowding between solvent atom planes, pushing their way into the lattice by distorting the planes themselves.

In any of these cases it will be seen that a certain amount of stiffness has been imparted by the imagined changes. The brick structure has certainly not been made more beautiful by the addition of the odd shaped bricks. But if a shearing stress were to be applied to the wall in the manner illustrated by figures 25 and 26 it would probably be found that sliding of smooth and regular courses would occur before any failure upon the courses in which the lines were spoiled by the bogus bricks. In the case of the cards, if a certain definite weight were to be placed upon each of the three packs and then a horizontal shearing stress again applied surely the fine, smooth cards would slip more readily than either the cheap ones or the good ones between which sand had been scattered.

If figure 24 conventionally represents a section of a simple, perfect lattice of one metal, figure 27 may similarly represent a portion of a crystalline solid solution or alloy, where the atoms of the solute *replace* atoms of solvent, and figure 28, one where solute atoms crowd *between* atoms of the lattice. The last two drawings differ from that of figure 24 because we now find it desirable to distinguish between the position of atoms of the solute and those of the solvent. So the latter are here represented by open circles, the former by black circles.

Remembering that deformation of a metal by stress, whether this

be pressure or any other kind of stress, is really a matter of gliding of crystal planes over each other, also that strength means *resistance* to gliding under stress, and it may readily be imagined that the roughened planes of the alloy will not glide over each other as easily as the original perfect planes would have done. The alloy is, therefore, harder and stronger than the pure solvent metal since either stretching or indenting ultimately involves permanent deformation of individual grains.

One more interesting extension of this idea. A foreign metal dissolves in another pure metal, easily or with difficulty according to its similarity (or lack of it) to the first. Of course this holds only within the range of composition where the second metal is in complete solid solution.

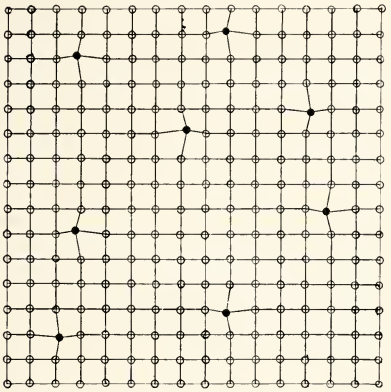


Fig. 27—Effect of dissolved foreign atoms upon crystal planes, where solute atoms displace atoms of solvent.

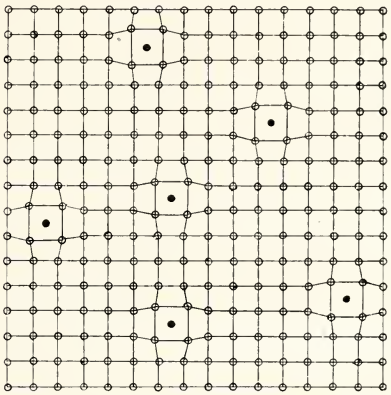


Fig. 28—Effect of foreign atoms upon crystal planes where solute atoms crowd between solvent atoms.

This is not difficult to understand. Races and communities follow similar rules. The more nearly the immigrant is like the people of the country or community, the more readily is he assimilated without undue commotion or disturbance. In the case of the metals, if the second one dissolves easily in the first this means that it takes its place in the crystal lattice with comparatively little disturbance of the perfect planes of that lattice, while if its solubility is small it is (chemically and physically) unlike its solvent and therefore it causes a correspondingly greater distortion or roughening of the atom planes.

If this be even an approximately correct view of the matter one may conclude that resistance to gliding ("slip resistance") will be, qualitatively at least, inversely as solubility, and we are therefore in possession of some sort of notion to explain the undoubted fact that *the greatest strengthening and hardening effects in alloys are produced by alloying metals whose mutual solubility is relatively small.*

A few examples may be noticed. Gold has been mentioned as being much used for ornamental and protective purposes and for coinage. But gold is quite soft and it would be relatively useless for these pur-

poses if it could not be hardened in some way. A number of metals will readily alloy with gold—some of them very easily. For practical purposes most of these are excluded because they would destroy this immunity to corrosion; and a large solubility is noticed in the case of the metals which do not themselves oxidize easily (the "noble" metals). It is, therefore, not possible to produce an extraordinary degree of hardening by the addition of such metals. However, an alloy of 90 per cent gold with 10 per cent copper is distinctly harder than gold, and it serves well enough for coinage. This is the alloy used by the government of the United States. Ordinary gold jewelry is of gold-copper composition, the proportion of gold being indicated by the number of "carats," 24 carats indicating pure gold. (Eighteen carat jewelry is therefore 18/24, or 75 per cent, gold.)

The brasses, bronzes, aluminum bronzes and Babbitt metals are other illustrations of this principle. And attention will again be called to the steels, which are essentially solid solutions of carbon in iron, especially after they have been given certain thermal treatment for hardening and strengthening. The hardening effect of carbon upon iron is very pronounced and its solubility in iron is correspondingly small. The steels are therefore very much stronger than pure iron.

The myth of "hardened copper" of the ancients is one that seems hard to dispel. It is a poor year for fakirs when at least one does not "rediscover" the "lost art." Scientific investigation invariably demonstrates that if the copper has been hardened at all, it has been either by cold work—which is not by any means a lost art—or by alloying small amounts of other metals with the copper, after which it is not copper but a copper alloy.

Lead is used in large quantities for the manufacture of the plates of ordinary storage batteries. But this metal is quite heavy and, at the same time, quite soft. Especially for use in batteries of portable nature, such as those used in automobiles, the metal would not sustain its own weight without injurious sagging. It is therefore hardened and stiffened by alloying with it a small proportion of antimony. A similar reason accounts for the use of antimony as an alloying constituent of type metal, which is otherwise largely of lead.

Grain Size. Another property vitally affecting the strength of metals is the average size of the crystalline grains composing the mass. Upon the assumption that the cellular envelopes which enclose the grains and separate them from each other are amorphous, and that amorphous metal is harder and stronger than crystalline metal, there is provided an explanation for the observed fact that when a metal is stressed to the point of fracture, the break runs normally *across* the grains and not around them. While it is not easy to prove experimentally that these grain boundaries are actually amorphous, it is certainly true that they are stronger than the grains themselves.

The particular direction in which the axes of a given grain are inclined, relatively to those of other grains, (the orientation of the grain) is more or less a random matter. On this account the "cleavage planes"—atom planes along which either slip or fracture occurs—of the

various grains will be directed, or oriented, without any regularity and again at random with relation to each other. This is seen in figure 14, where the slip bands change their direction at grain boundaries. When a piece finally breaks, the *macro*scopic appearance of the fracture is that of a multitude of bright facets, each being a section across a grain of metal. This is why a metal fracture is always more or less rough in appearance.

The Effect of Grain Size Upon Strength. The failure of a piece of wood under stress is usually a matter of splitting along planes represented by the fibrous structure of the wood. A fine, straight-grained wood splits more readily than one of twisted grain, as illustrated by oak and mahogany, respectively. If even the oak wood is full of sound knots, the wood is less susceptible to mechanical failure. The obvious reason for this is that the cleavage planes are interrupted by the knots or twisted fibers, with a corresponding change in the direction of the fracture. The dividing forces of the tool are not exerted in a way to suit this change.

This effect is still more striking when one considers a piece of two-ply or three-ply wood, with one thin board glued to another which has its grain oriented in a manner perpendicular to that of the first.

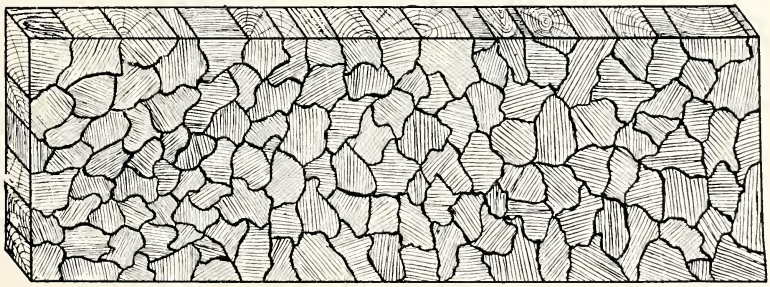


Fig. 29—Diagram of a composite block of wood, showing strengthening effects of random orientation.

Figure 29 is an imaginary representation of a piece of wood, compounded by gluing together a number of "polyhedral" blocks, each of straight-grained material, but with the grain of these blocks oriented in all sorts of directions. If the glue which has been used is as good as its manufacturers advertise, the glued joints are actually stronger than the wood itself and the analogy with the metal is complete. It will not require much debate in order to decide whether this composite specimen will be more or less easily pulled apart or crushed than would be the case with a single piece of straight-grained wood of the same dimensions.

The individual grains of the metal may be likened to the irregular blocks of figure 29. Every time a break reaches a grain boundary it has to change its direction. In addition to this, it has to run across an envelope of stronger metal. Also (and this consideration does not apply

to the piece of wood) *before* fracture a plastic deformation of the grain would have to occur to a considerable extent. As such deformation consists of slips on crystal planes, it is resisted if planes of neighboring grains are not disposed so as to continue the slip without change in direction.

It will then be seen why it is that fine-grained metal is stronger than coarse-grained; for the more frequently the inclination of slip planes is changed, the greater will be the resistance—first to slip and then to fracture.

Vibration and Crystal Growth. Most people have heard the statement that a particular piece of metal broke in service "because it had crystallized as a result of vibration." This is a mistake, for the simple reason that, with a few unimportant exceptions, metals do not crystallize or change their crystal size as a result of vibration. They are crystalline as soon as they freeze from the liquid state and they remain in that condition. Breaks of the character just mentioned are usually due to a phenomenon known as "fatigue." Sometimes they are due simply to the fact that the metal was defective in the beginning.

But this notion about metals crystallizing under vibration is as hard to dispel as the one about an ancient lost art of hardening copper. The reasoning at first seems valid. A piece of steel (say, of a bridge structure or of an automobile axle), subjected to continued vibration under intense stress, breaks. Examination of the fracture shows that it is very rough, and that the metal was therefore coarsely crystallized. The conclusion is reached that vibration has crystallized the metal, or that it has increased the average grain size.

If one should make a microscopic examination of a piece of steel, find that it is fine grained, subject it to repeated intense stresses until it breaks, and then re-examine and find coarse grains, the case would be established. But the coarse grained axle or bridge structure had not been so examined before it went into service and that bit of evidence is lacking. On the contrary, the complete experiment has been performed in the laboratory over and over again, and there is no manner of doubt now that repeated stresses have no effect whatever upon grain size or structure unless these stresses are above the elastic limit, thus causing permanent distortion before fracture.

The Structure of Eutectoids. When two metals are melted together there is usually some temperature range within which they form a homogeneous mutual solution. Upon cooling, the freezing point is usually lower than the average indicated by the percentage composition of the alloy and the freezing points of the component metals, but in many of these alloys there is some particular composition which gives an alloy having a freezing point lower than for any other composition. Such an alloy is called an "eutectic" and when the eutectic solution freezes, the metals fall out of solution and give a conglomerate of microscopic particles, this conglomerate being known as an "eutectoid."

The formation of eutectoid mixtures from eutectic solutions is a result of the simultaneous freezing of both components of the liquid

solution and this always gives rise to a very fine intermixture of these two solids. Solid eutectoids often show the structure of alternating microscopic plates of the two components; but sometimes they exhibit the characteristics of microscopic globules of one, dispersed in a matrix of the other. The patterns visible through the microscope are frequently very beautiful and a few of them will be shown here.

Figure 30 is a micro of a lead-antimony alloy. In this case the composition was "hypereutectic" (it contains more antimony than the eutectic) and the excess antimony appears as large bright crystals.

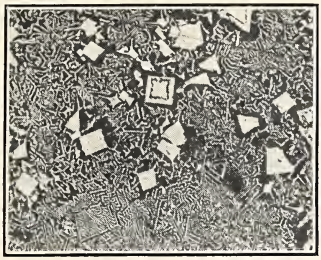


Fig. 30—Lead-antimony alloy, with eutectoid and antimony crystals. x50.

Fig. 31—Lead-tin eutectoid. x100.

Figure 31 is of the eutectoid of lead and tin, containing 37 per cent of lead and 63 of tin. The eutectoid of cadmium and tin (cadmium 29 and tin 71 per cent) is easily distinguished in figure 32. The globular grains are of tin, showing that the alloy as a whole was hypoeutectoid with respect to cadmium. The dotted portion of figure 33 is the eutectoid of a "white" cast iron. The eutectoid of iron and iron carbide (pearlite) has already been shown in figure 12.

Steel. Steel is a material in which iron is the chief constituent, but which contains also small percentages of carbon. There are always present also small quantities of impurities which cannot be entirely removed in the process of manufacture, such as phosphorus, sulphur, silicon and manganese, and there are in industrial use today large numbers of special steels, to which certain amounts of other metals have been added in order to confer desirable qualities upon the steel. Such materials as the last named are known, in general, as "alloy steels." The metals most commonly added are nickel, chromium, tungsten, molybdenum, vanadium, manganese and uranium.

Steels not classed as alloy steels are often designated as "carbon steels." However it is to be remembered that carbon is an essential constituent of any steel, whether alloy or not. That is, if carbon is not present, we do not have a steel at all, but rather an alloy of iron with the added metal or metals.

Steels possess an extraordinary capacity for response to thermal treatment, the rate of heating and cooling profoundly affecting the hardness, tensile strength, elastic limit and ductility. This fact makes this class of alloys exceptionally useful in industry.

Fatigue. When a man becomes very tired he wants to quit working. If he cannot quit he goes into a state of excessive fatigue and any

physician will say that the body in such a state is an easy prey to disease-producing organisms. Possibly this is why a metal, under severe service for a long time where the stresses are repeated or alternated in direction, and finally failing, is said to have yielded to "fatigue."

Metal does not become "tired," as do living bodies, but there is a certain analogy, after all. If the severe stress, even below the elastic limit of the piece as a whole, is of an alternating or repeating character, as when a piece of machinery is subjected to intense vibration under stress, a microscopic failure may begin at one of the weaker spots. It may then spread, simply because its own proper load is thrown upon the parts immediately surrounding it and this load is more than even they can bear. The spreading of failure is so slow as to be imperceptible at first, and the piece may last for a long time. But failure gathers speed as it spreads and the piece finally breaks.

Automobile axles frequently break in this way. The stress which is applied through the drive shaft and differential is of a pulsating character and the direction of stress caused by the weight of the car is constantly changing as the wheel turns. For a long time before the break occurs, no crack of any kind could be seen. But at the last it goes rapidly and the axle finally yields suddenly.

Cast Iron. This term is more or less of a misnomer because cast irons actually contain more carbon, and usually more of the common impurities, than steel itself. But the designation sticks, as do many of the names of materials and processes of older origin.

There are three general classes of cast irons, known respectively as "white," "gray," and "malleable." As the first named class is the only one which conforms to the general principles already discussed, it should be considered first.

White Cast Iron. Although liquid iron will dissolve carbon to the extent of about 6.7 per cent of the total weight of the alloy, much of this carbon will separate in the free state unless hindered by the presence of restraining elements—of which manganese is most commonly used—or by fairly rapid cooling, or by both influences. If these steps are taken to prevent the formation of free carbon, the resulting casting is found to be exceedingly hard. If broken by the application of large stresses it will fail without any appreciable previous deformation, which proves its ductility to be practically zero. The broken surfaces are then brilliant and of light metallic luster, hence the name "white" cast iron.

The microscopic structure of white cast iron is shown in figure 33. On account of the large amount of hard iron carbide, castings of this material are so brittle and so hard, and therefore difficult to drill or machine, that they are not often made except as a first step in the production of "malleable" castings.

Gray Cast Iron. In castings of such high carbon content, a change takes place after the casting has solidified, unless precautions have been taken to prevent it. While the iron carbide of steel is quite stable—no doubt partly on account of the lower temperature at which it separates from the solid solution—the carbide of cast iron begins a chemical decomposition as soon as it has been formed from the liquid solution.

As a result of this, free carbon forms, and remains as branching masses within a matrix of ferrite grains.

Photomicrographs of this form of cast iron are shown in figure 34. The bright portion is of ferrite grains and the black masses are of free carbon, known here as "graphite." When a casting is broken the abundance of exposed graphite, intermixed with bright facets of ferrite grains, gives the fracture a gray appearance, which is responsible for the name of this class of castings. As the ferrite, ductile though it is, is so "honey-combed" with these branching masses of carbon, the castings are relatively weak and easily broken by shock.

Fig. 32—Cadmium-tin eutectoid with excess of tin. x100.

Fig. 33—White cast iron. x100.

Fig. 34—Gray cast iron. x100.

Fig. 35—Malleable cast iron. x100.

One may be inclined to wonder why gray castings are ever made at all, in view of their poor strength characteristics. This is explained when we remember that such castings may be made from a moderately good grade of pig iron. As pig iron is the starting point for most of the steel making processes, the entire expense of steel making is avoided by the use of gray castings and the cost is reduced to the point where it is, in some cases, economical to provide the necessary strength by increasing the mass of the casting. The cost of the extra necessary material itself is thus more than compensated by the saving in the expense of refining.

So it happens that gray iron is used for purposes where a larger weight is not objectionable (or where it is even desirable, from the standpoint of general stability) or where much drilling or grinding is

to be done with the casting. As examples there may be mentioned the heavy bases for supporting machinery, many of the heavier parts of the machinery itself, cylinders of locomotive and automobile engines, heavy railway car wheels, and water and sewer pipe.

Malleable Castings. The carbon of gray iron has begun to separate from iron carbide as soon as the casting has become solid, continuing as cooling progresses. If the composition and cooling rate are so adjusted as to produce white iron, and if then the casting is reheated, free carbon will slowly form but the appearance of the masses will be different. Instead of the curved branches of the graphite of gray iron, extending through the mass of ductile ferrite and weakening it, the carbon forms in more compact bunches, leaving the ferrite in sounder condition.

Figure 35 indicates why this class of castings is of greater strength than gray iron and why it will withstand greater shock without breaking. As in gray iron itself, the most of the metal is ferrite grains but now the free carbon is in these smaller and more compact masses. This carbon is called "temper carbon," although the only difference between this and the graphite of gray iron is in the form of the microscopic aggregates.

"Malleable" castings are not highly malleable, as compared with pure iron. They cannot be cold-worked to any considerable extent, although bars not too thick may be bent through a considerable angle without breaking. But they will withstand both shock and slow stresses much better than gray castings. They are therefore used where the massiveness of gray castings is not permissible, but where the strength of steel is not required. The small castings of "link" belts for agricultural and other machinery, the elbows and unions used for pipe fittings, many of the small castings of automobiles, and other similar articles, are generally made of malleable castings.

CONCLUSION.

It will have become perfectly obvious to those who have listened to this address that no systematic or complete discussion of the field of metals and alloys was expected to be accomplished. A recent list published by the American Society for Testing Materials contains the names and compositions of more than fifteen hundred alloys, not even including the various irons and steels. And the list is far from being complete. A survey of such a vast field is clearly impossible in such a paper as this. Many excellent books upon these subjects are available to the student of metallurgy who may intend to devote himself to an extended study of the subject.

On the contrary, I have tried to keep in mind just what is indicated by the title to this paper. The application of the microscope to the study of metals is a subject which is so fascinating and so useful that it has seemed desirable to attempt to bring some sort of understanding and appreciation of the results of the use of this marvelous instrument to some of those who are interested in the subject, but to whom the study of metallurgy as a science may have seemed appallingly deep and intricate.

A CONTRIBUTION TO THE PHYTOECOLOGY OF SOUTHERN INDIANA WITH SPECIAL REFERENCE TO CERTAIN ERICACEAE IN A LIMESTONE AREA OF THE BLOOMINGTON QUADRANGLE.

WINONA H. WELCH, Indiana University.

Since Bloomington is situated in a portion of Indiana which is noted for its limestone, and since the distribution of Ericaceae is thought to be influenced greatly by soil acidity, the writer has been interested especially in studying the distribution of the huckleberry (*Gaylussacia baccata*) and the blueberry (*Vaccinium vacillans*) on cer-

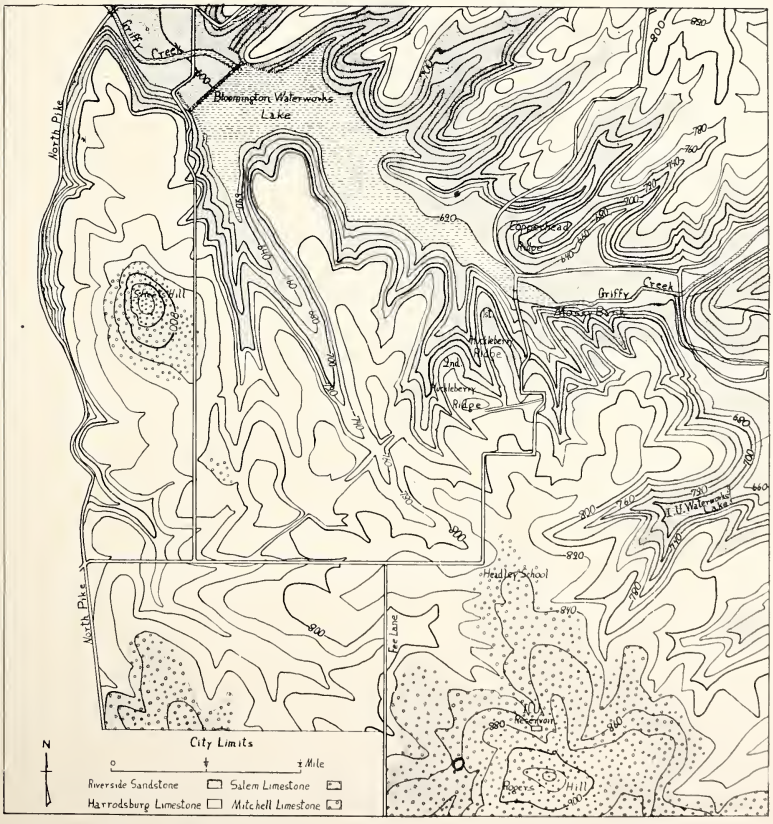


Fig. 1—Map showing the topography and the rock formation.

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tain ridges and slopes northeast of Bloomington, the processes which have produced situations favorable for the growth of Ericaceae in this particular area, and the degree of acidity of the soil in which these plants are most commonly found.

Also, in the same area, a study has been made of plant indicators of soil acidity, two glacial relics near Bloomington, general vegetation and habitats, zones of vegetation at the head of the lake, and hydrarch succession in a solution pond.

Location and Climate of Area. The area chosen for this study consists of four square miles northeast of the city of Bloomington (fig. 1).

The average temperature in the southern part of Indiana for January is 33° F.; for July, 79° F. (14). The mean annual temperature is 52° F. The average rainfall is 42 inches, rather evenly distributed throughout the year (7). The mean relative humidity for Indianapolis (approximately 50 miles northeast of Bloomington) and vicinity is 78 per cent at 7 a.m., 59 per cent at noon, and 64 per cent at 7 p.m. (19).

Topography. This area is a portion of the late Tertiary peneplain and is very much dissected by Griffy Creek and its tributaries. As a result, a series of ridges and ravines extend toward the Griffy Creek Valley. The ravines are small and V-shaped, with steep sides. At the head of each is a steep fall of 10 to 15 feet (10) where the Harrodsburg limestone comes in contact with the Knobstone. After the valleys have reached their local base-levels they are no longer V-shaped, but become flat-bottomed areas with steep ascents on their sides. In the Bloomington Quadrangle, Griffy Creek flows from southeast to northwest. In this particular portion under observation the streams forming the ravines on the north side of the valley flow from northeast to southwest, and those on the south side flow north and northwest.

Geology. "Approximately 30,100 square miles of Indiana have been subjected to glaciation, while only about 6,250 square miles have not been touched by glacial ice. The unglaciated area in the middle-western portion of the southern third of the state is frequently spoken of as the driftless area as opposed to the glaciated area" (11). The largest part of Monroe County lies in the unglaciated portion, and the bedrock formations are well exposed. The Illinoian ice sheet extended farther south in Indiana than either the early or the late phase of the Wisconsin. Figure 2 shows the glacial boundary in the state as determined by C. A. Malott (9), in 1925.

The area included in this investigation lies within the portion of the Bloomington Quadrangle which is occupied by the Knobstone and by the Harrodsburg, Salem, and Mitchell limestones (3). Figure 1 shows the position of the rock outcrops, their thickness, and the manner in which the different formations rest upon each other. The outcrops of the Knobstone and the Harrodsburg limestone occur frequently in the area selected for this study.

Only the upper portion of the Knobstone is exposed in the Bloomington Quadrangle. This part of the formation is known as the Riverside sandstone (8). Approximately 100 feet of the sandstone are exposed

in this vicinity. The Knobstone is visible in the ravines and especially well at the northeast end of the spillway of the Bloomington Water Works Lake. The sandstone consists of fine grains of sand cemented with clay. It is bluish gray in color and weathers to a light or rusty brown.

The Harrodsburg limestone of the Bloomington Quadrangle is from 70 to 90 feet in thickness (15). It is a very coarse limestone and is easily identified by the abundance of geodes and fossil crinoids and brachiopods contained within it. Outcrops of this rock are common on the west-facing slope along North Pike (State Road 37) and are observed frequently at the heads of the ravines. The geode zone of the Harrodsburg lies at the base of the formation and is frequently 15 or more feet in thickness. It extends into the Riverside sandstone for a distance of 10 or more feet (3).

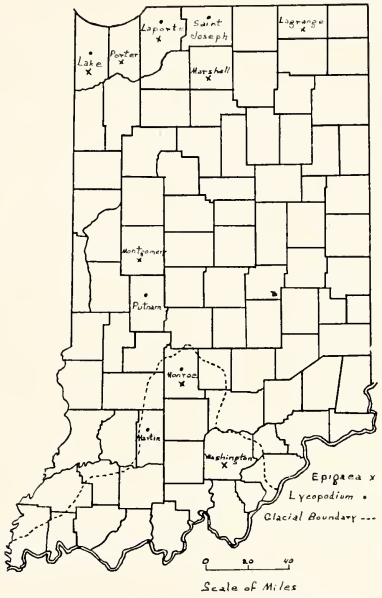

Fig. 2. Outline map of Indiana showing glacial boundary and county distribution of *Lycopodium complanatum* L., var. *flabelliforme* Fernald and *Epigaea repens* L.

Since the influence of the Mitchell and Salem limestones upon the vegetation of this area under study is not different from that of the Harrodsburg, their chief characteristics have been omitted from this discussion.

Beginning with the lowest formations in the Bloomington Quadrangle and passing to the uppermost ones, they occur in the following order: (a) the Knobstone or Borden, (b) the Harrodsburg limestone, (c) the Salem limestone, (d) the Mitchell limestone, (e) the Chester shales, limestones, and sandstones, and (f) the Pottsville or Mansfield sandstone. They occur in the same sequence from the lowest rocks in the valleys on the east to the highest ones on the hills in the southwest

part of the Quadrangle. The lower layers pass under the higher ones to the west or southwest with an average dip of about 34 feet per mile (3).

Method. Excursions were made over the selected area for the purpose of (a) studying all situations in which *Gaylussacia* and *Vaccinium* are growing, (b) observing how these habitats have been produced, (c) collecting soil samples for the determination of pH values, (d) studying the general vegetation and (e) collecting specimens of each species of plants growing within these four square miles.

Approximately 300 soil samples have been collected and the pH value determined by means of the Morgan Soil Testing Set (12). Many of these tests were checked electrometrically and only slight differences (0.1-0.3) in the pH values resulted. Six serial collections were made. Each series consists of samples taken in a direct line from the top of the ridge to the base of the slope. The remaining samples were taken at random, in order to determine the pH value of the soils in which the various species of plants are growing. A soil sample was taken in the following manner: the covering, such as sod, leaves, and debris, was removed, and a few handfuls of soil were dug to a depth of four inches, which is the approximate root level of *Gaylussacia* and *Vaccinium* in this area. After being thoroughly mixed this was placed in a clean, separate container and labeled. The testing was done in the laboratory, using air-dried soil.

Four hundred species of plants were collected from the area under study. Because of the lack of space the enumeration cannot be included with this discussion. The specimens, with a few exceptions, have been identified by the author, mounted, labeled, and preserved in the Indiana University Herbarium. All doubtful identifications have been checked by C. C. Deam, the species of Cuscuta by T. G. Yuncker, and the grasses by Paul Weatherwax.

Distribution of Gaylussacia and Vaccinium. Huckleberries and blueberries grow widely distributed in the eastern part of Monroe County, and occasionally quantities of the fruits are brought to the Bloomington market in season. Second Huckleberry Hill is the point nearest to Bloomington from which these species have been reported. The writer has found these plants growing on slopes in all portions of the area except that which lies west of Second Huckleberry. The geologic and edaphic factors seem to have played the most important part in the distribution of *Gaylussacia baccata* and *Vaccinium vacillans* in this particular region.

The three upper rock formations consist of limestones (figure 1). Cumings (7) states that analyses of the Salem show from 97.9 per cent to 98.4 per cent calcium carbonate, with the balance consisting mostly of clay, and iron oxide, and of the Mitchell, 96.65 per cent to 99.04 per cent calcium and magnesium carbonate, with the balance consisting of clay, and iron oxide. He also states that satisfactory analyses of the Harrodsburg have not been obtained, but that it contains less calcium carbonate than the other two formations.

Most of the slopes along Griffy Creek in the area under consideration are densely wooded, except where man has cleared them for lumber or for fuel. The ridges are pastured or cultivated. Figure 1 shows the wooded slopes and the open ridges, comparable with sandstone and limestone areas respectively.

Since carbon dioxide is produced abundantly by living organisms in the surface layers of woodland soils, and by the decomposition of vegetable matter, the rainwater, as it passes through the atmosphere just above the ground level and through the upper portion of the soil, absorbs the gas, and carbonic acid is formed. This carbonated rainwater has a marked solvent action upon the limestone, dissolving both the calcium and the magnesium carbonate. Leaching is therefore one of the most important factors influencing the distribution of huckleberries and blueberries in a limestone area.

The ravines begin with a steep fall of about 10 or 15 feet at the contact point of the Harrodsburg limestone and the sandstone. An exposure of the limestone commonly occurs at the head of each ravine. The streams have cut their valleys through the higher (limestone) formation into the underlying rock. Because of erosion the limestone has been washed away and the sandstone is the only formation visible on the bottom and sides of the V-shaped ravines. Limestone ledges frequently occur on the sides as well as at the head of the older, U-shaped ravines. But in all cases the sandstone forms the bottom. Geodes are found frequently in these gullies, the presence of which is an indication that the contact between the Knobstone and the Harrodsburg limestone has been reached. Smaller ravines enter the larger ones, and the latter extend into the lake. Frequently young trees ar found lying across the V-shaped ravines, having fallen as the result of erosion. Other evidences of this process are the dead or dying trees and shrubs along the margins of the younger gorges where erosion continuously carries the soil and pieces of rock away from the roots. Occasionally, where sufficient soil has lodged, herbaceous plants grow in these V-shaped ravines.

The bows or bends in the trunks of the trees which grow on the slopes give evidence of slight land-slides. The roots of plants, especially the trees and shrubs, hasten disintegration of the rock. The woods are moist and shady. The sandstone, although not well exposed to the sun's rays, shatters and weathers as a result of freezing and thawing. Often large pieces are broken loose by frost action. As the disintegration and exfoliation continue, conditions are produced eventually which are so unstable that gravity causes landslides. After the slip, the plants readjust themselves to their new surroundings.

Figure 1 shows the dominance of Knobstone slopes along the Griffy Creek Valley, and a comparison of the exposures of this formation makes evident a difference of approximately 100 feet between the Knobstone exposure on the west side of the area, along North Pike, and that on the east. This is due to the dip of the rock formation to the west or the southwest.

The south-facing slope is much more gradual than the one opposing it. The ravines on this side of the lake are longer and more numerous.

These conditions indicate that a greater amount of erosion has occurred on these slopes than on those sloping northward. The difference in weathering of the slopes is due to the effect of changes in the temperature, especially of freezing and thawing, upon the rocks. The slopes facing northward are protected from the rays of the sun and are frozen throughout most of the winter. During the same period, the rocks of the south-facing slopes are repeatedly frozen and thawed, because these slopes are exposed to many more changes of temperature. Therefore a greater amount of soil and exfoliated rock is in condition to slide down the slopes into the ravines and the lake under the influence of gravity, or to be carried down by the water.

Mechanical weathering occurs more rapidly in the sandstone than in the limestone, because the former, due to its power to absorb water, is easily disintegrated by frost action. The exposures of the sandstone are sloping and those of the limestone are vertical. Chemical action occurs much more slowly in siliceous rocks than in calcareous rocks because the carbonate of lime, the essential constituent of ordinary limestone, is highly soluble in carbonated rainwater and, in time, may be completely removed.

The results of erosion are commonly more distinct on the west-facing slopes than on those facing the east, because the former usually have a higher daily temperature than the latter. Thus conditions are produced which are similar to those on south-facing slopes, although they are not so advanced.

Tests show that the soil on the slopes is acid. The writer considers that the following conditions may account, in part at least, for this acidity: (a) the presence of inorganic acids, especially carbonic acid. (b) the presence of various organic acids, and (c) the lack of sufficient basic elements to counteract the acidity.

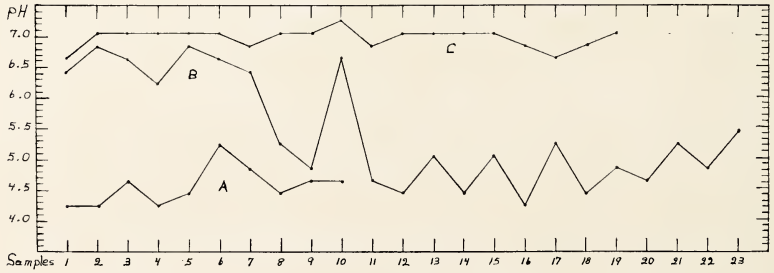

Fig. 3. Variation in soil acidity on three different slopes, A, B, and C, and in different portions of the same slope. In each of the series the first sample was taken at the top of the slope and a direct line was followed to the base. Samples were taken approximately every 20 feet.

The degree of acidity varies on different slopes (table 1) and in different portions of the same slope (fig. 3). The soil of the slopes in the eastern part of the area is more acid than that in the western (table 1), including a distance of only two miles, due to a greater exposure of limestone along North Pike (fig. 1).

Table 1 also shows that, with one exception which is explained in the preceding paragraph, the pH values on the north-facing slopes are higher than on those facing the west. As explained before, less weathering and erosion have occurred on the slopes facing north, and for that reason there still remains sufficient limestone to decrease the soil acidity to that extent.

TABLE 1. The Decrease in acidity of the Soil from the eastern portion to the Western Portion of the Area Studied, and on the North-facing slopes.

Location	pH Range
West-facing slope on east side of area	4.2—4.6
North-facing slope of Mossy Bank	4.6—5.0
West-facing slope of Mossy Bank	4.4—4.6
North-facing slope of First Huckleberry	5.2—6.4
West-facing slope of First Huckleberry	4.2—5.2
All slopes of Second Huckleberry	4.4—6.4
North-facing slope of 1st ridge w of 2nd Huckleberry	5.0—6.6
North-facing slope of ridges between 2nd Huckleberry & North Pike	4.6—7.0
West-facing slope along North Pike	6.6—7.4

The pH values in three series of soil samples are shown in figure 3. Each series was taken on different slopes and shows the variation in acidity in different portions of the same slope. A direct line was followed from the top of the ridge to the base of the slope. Series A was taken on a south-facing slope on the north side of Griffy Creek where blueberries grow abundantly. Series B was collected on a south-facing slope on the north side of Griffy Creek, but no blueberries grow on this slope. This series shows the increase of soil acidity in the lower portion of the slope, which results from leaching and particularly erosion, in the past. In the upper portion, the soil is circumneutral, i. e., between 6.0 and 8.0. Approaching the limestone formation where there are still many fragments of limestone in the soil, the degree of acidity is lessened. The presence of small pieces of limestone is the probable cause of the more extreme irregularities in series A and B. Series C was made on the west-facing slope along North Pike. Limestone outcrops are very frequent and no species of Ericaceae are found on this slope. All the soil in this series is circumneutral, due to the presence of the limestone.

The author has found abundant evidence that the distribution of *G. baccata* and *V. vacillans* in this particular area is closely connected with the acidity of the soil. Having made approximately 100 tests of the soil in which these species are growing throughout the entire area, the pH range has been determined as 4.0 to 5.2, 4.4 being the most frequent value, as is shown in Table 2.

These species grow along the margins of the ridges and on the slopes, usually more abundantly toward the top than the base, and particularly on the points of the ridges, if erosion is not too severe. The direction of slope and the angle, although commonly about 25°, are

not extremely important factors. Although *Gaylussacia* and *Vaccinium* are usually growing more abundantly on south-facing or west-facing slopes in the area under consideration, they may be found occasionally on slopes facing the north. The upper extent to which they grow depends upon the acidity of the soil, which, in turn, is influenced by the amount of limestone in it, and this is dependent, largely, upon the degree to which leaching and erosion have occurred. The lower range is limited by the erosive factor because the roots of the species do not penetrate deeply into the soil.

TABLE 2. Soil Reaction Preferences of *Gaylussacia baccata* and *Vaccinium vacillans*.

Percent of Soil Tests	pH Value
74 plus	4.4
11 plus	4.6
5 plus	4.8
4 plus	5.0
2 plus	4.2
2 plus	5.2
1 plus	4.0

They grow in clumps because they spread chiefly by vegetative means. These plants reach new habitats by dissemination of their fruits and seeds by means of animals, especially birds. Frequently the huckleberries and blueberries are retained by the roots of other shrubs and of trees, or by large pieces of rocks, while the remainder of the slope is bare due to erosion. In a number of instances the depth of the soil in which the Ericaceous plants are growing was measured. In all cases, about four inches below the surface the roots were found to be growing among small pieces of sandstone.

In this specific area *Gaylussacia* and *Vaccinium* show the most luxuriant growth in open or exposed situations. The sandstone soil retains very little moisture because of the clay cement and the fineness of the sand grains. Therefore these species occur in xerarch succession. One of the south-facing slopes shows the following stages from a bare area to the climax forest. This bare area has been produced by water erosion. Beginning at the base of the slope, a few feet above the water's edge, the first plants seen are the fruticose lichens, usually some species of *Cladonia*, and mosses such as *Dicranum scoparium* (L.) Hedw., *Leucobryum glaucum* (L.) Schimp., and *Polytrichum commune* L. Continuing up the slope, grass grows with the pioneers. Still farther upward *Vaccinium vacillans* accompanies the grass, mosses, and lichens. The blueberries are a part of the shrub stage which also includes *Viburnum acerifolium*, but this species occurs a short distance beyond the *Vaccinium*. *Quercus alba*, *Q. velutina*, and *Carya cordiformis*, xeric trees, follow the shrub stage, and grow on the upper slope and the ridge with the climax trees, *Acer saccharum* and *Fagus grandifolia*.

Reasons for the non-occurrence of *Gaylussacia* and *Vaccinium* west of Second Huckleberry follow. The slopes are densely wooded. In these moist and shaded situations the sandstone weathers by exfoliation and forms an unstable substratum. The soil is loose and contains a great amount of humus. The vegetation consists of the climax trees, with their associates, a few large shrubs, and the common woodland herbaceous vegetation. Because of the abundance of root systems, no great amount of soil is carried away by erosion. No exposures of the Knobstone occur except in the V-shaped ravines, where erosion prevents the growth of these shrubs. The limestone has weathered to a lesser extent, and outcrops of this formation occur frequently. As is shown in Tables 1 and 2, the degree of soil acidity is not sufficiently great. Since erosion has not advanced as rapidly on these particular slopes as on others, fragments of limestone resulting from weathering are still sufficiently plentiful in the soil to decrease the soil acidity to the extent that *Gaylussacia* and *Vaccinium* do not grow in this portion of the area. On the upper west-facing slopes there occurs rarely a small, open, dry area on which mosses and fruticose lichens are growing. They are the same species which accompany the huckleberries and blueberries in other habitats. Thus it seems reasonable to predict that sometime in the future when the conditions preferred by *Gaylussacia* and *Vaccinium* exist on these particular slopes, these plants will take their place in the shrub stage of this xeric succession.

Plant Indicators. Throughout the area the author found that certain plants were always growing in acid soil. A list of these species was made and numerous soil samples were tested. Table 3 includes the names and the range of pH values. The asterisk refers to those species which commonly grow in the same society. The others may or may not be found with these.

TABLE 3. Plant Indicators of Acid Soil in This Specific Area.

Species	pH Range
**Gaylussacia baccata*	4.0—4.6
**Dicranum scoparium*	4.2—4.8
Danthonia spicata	4.2—5.0
Monotropa uniflora	4.4—5.0
**Mitchella repens*	3.8—5.2
Pedicularis canadensis	4.4—5.2
**Carex picta*	4.4—5.4
**Leucobryum glaucum*	4.2—5.4
**Polytrichum commune*	4.2—5.4
**Vaccinium vacillans*	4.2—5.4
**Viburnum acerifolium*	4.2—5.6

Glacial Relics. Since the range of *Lycopodium complanatum* L., var. *flabelliforme* Fernald and *Epigaea repens* L. is southern and southeastern Canada and northern and northeastern United States, how did

each of these species reach southern Indiana? Although the question cannot be answered with assurance the following explanation seems probable.

The Illinoian ice sheet reached the Ozark Hills in southern Illinois. A short distance east of the Indiana-Illinois line the glacial drift bends to the northeast and continues this direction to central Indiana (figure 2), where it turns south to the Ohio River, and continues east into Ohio.

While the tundra extended along the front of the ice during the period of glaciation the soil was probably frozen to a great depth, but thawed in summer sufficient for the growth of plants. When the ice retreated in Indiana and Ohio it was separated from the forests by this treeless tundra.

In order to continue with the theory it is necessary to understand the habit and conditions of growth of the species under consideration. *Epigaea repens* spreads over the ground in large patches, by means of branches 6 to 15 inches long which send out roots, a leaf, and flower-bearing stalks every two or three inches. The white, fleshy, juicy fruit contains usually 300 to 500 seeds according to Bailey (2). Since ants, snails, and birds seek the pulp of the fruit it is possible for these animals to disseminate some of the seeds and thus aid in the development of new patches of trailing arbutus in suitable habitats. *Epigaea repens* thrives in acid, sandy, well aerated, moist soils in shady situations (2). Its roots imbedded very shallowly in the soil possess a mycorrhizal fungus (6) which is assumed to be beneficial to the host because it seems to supply the plant with sufficient nitrogen to enable it to live in its chosen habitat.

Figure 3 shows the distribution of *E. repens* in Indiana according to C. C. Deam. The writer has collected it in Monroe County, on Arbutus Hill, four miles east of Bloomington and has seen a specimen which was collected in Washington County. This plant grows also in various other known localities in Monroe and Brown counties. Upon examination of the glacial boundary in Indiana it is noted that Montgomery County has been entirely glaciated, and that small portions of Monroe and Washington counties lie within the limits of the ice sheet. According to the theory of the writer *E. repens* was one of the species growing in the tundra zone along the ice front, and, as the glacier retreated, the plants in the most suitable habitats survived. Thus it is possible for this species under consideration, now growing in Montgomery, Monroe, and Washington counties, to have descended from the trailing arbutus of the tundra.

Perhaps *Epigaea* grew more commonly in southern Indiana following the retreat of the ice than at the present time, and possibly the forest fires started by the Indians have played an important rôle in almost eliminating this beautiful trailing plant from the flora of this part of the state. Or perhaps trailing arbutus always has been of rare occurrence in this portion of North America. In either case, whether common or rare, what has prevented its extinction? The most plausible answer seems to be that this species is found in a habitat which is

much more favorable for its growth than for the majority of the neighboring species. It is probable that soil acidity is the factor to which *E. repens* is so well adapted, and, due to this adaptation, this trailing arbutus has been able to survive in competition with the other plants. The pH values of the soil samples collected on Arbutus Hill are 4.0, 4.2, and 4.4.

Man is fond of the flowers and their fragrance and injures the roots and trailing stems each time a bouquet is gathered. Others collect for transplanting, which is nearly always unsuccessful. These facts account for its low rate of spreading, which occurs chiefly by vegetative means, and, if proper precautions for the preservation of the species are not taken, will bring about the extinction of trailing arbutus in this locality. Otherwise *E. repens* should thrive as long as the necessary soil conditions are present.

The other glacial relic, which the author wishes to consider in this discussion, is *Lycopodium complanatum* L., var. *flabelliforme* Fernald. The sporophyte consists of a long, nearly superficial rhizome which produces roots at intervals from the lower side and erect branches from the upper portion. The spores are produced in cone-like structures which develop at the ends of the several-forked branches and are ripe in August or September. The prothallia of this species are subterranean. They have not been collected in this locality. Stokey and Starr (18), collecting in western Massachusetts, found the prothallia at depths varying from 0.5 to 4.0 centimeters. They also report that in two cases prothallia and sporelings were found within 3 meters of old plants; usually they were 15 to 50 meters apart; occasionally 100 to 200 meters away. Spessard (17) records finding only a few sporelings growing among the plants. A fairly compact, well drained, sandy soil with considerable humus and an adequate supply of moisture, in a shaded area with little or no herbaceous growth, plus the fungus which is assumed to be necessary for the endophytic relationship with the prothallia are the conditions generally found where gametophytes and sporelings of *Lycopodium* have developed.

Blatchley (4) reports *Lycopodium complanatum* L. (probably the variety) as rare on Huckleberry Hill in 1887. Andrews (1) states that he saw it "about 30 years ago on the western slopes of several deep ravines about two miles northeast of Bloomington, Indiana." The author has been informed by the teachers in the Botany Department of Indiana University that the presence of the sporophytes of the ground pine on First and Second Huckleberry Hills is intermittent. One of the professors found them in 1915 and not again until 1922. Since the latter date it has not been reported from that particular region.

In May and October, 1927, the writer visited a community of this club moss on a slope about four miles north of Bloomington. This patch covers an area approximately one rod square, and is located about one-half the way down a high, rather steep, north-facing slope, at the base of which runs a stream. The common trees of this region, such as *Acer saccharum, A. rubrum, Fagus grandifolia, Quercus alba, Q. Prinus, Morus rubra, Prunus serotina, Liriodendron Tulipifera, Nyssa*

sylvatica, Carpinus caroliniana, Ostrya virginiana, Cornus florida, Sassafras variifolium, and *Fraxinus americana,* shade the slope, cover the ground with leaves in the fall, and greatly increase the supply of humus each year. The herbaceous vegetation within the immediate vicinity of *Lycopodium* is scanty and consists of the following species: *Polystichum acrostichoides, Adiantum pedatum, Polytrichum commune,* and *Leucobryum glaucum.* The *Lycopodium* is growing in a soil which is subacid with a pH value of 5.4.

Figure 2 shows the distribution of this species in Indiana by counties. In the southern part of the state it has been reported from Putnam and Monroe counties. The larger portion of the latter lies in the zone which was tundra along the ice front, and probably the ancestors of the *Lycopodium* now growing in Monroe County were growing in the tundra. The entire portion of Putnam County lies in the glaciated area of Indiana, and *Lycopodium* doubtlessly established itself there as the ice retreated. The same points discussed in connection with *Epigaea repens* may be applicable in considering this club moss, namely, forest fires started by the Indians, frequency or rarity of occurrence, and its survival in limited areas under favorable conditions in competition with other plants. The small patch on the hillside mentioned is on private and carefully protected property and is thriving due to its suitable habitat.

According to Stokey and Starr (18) and Spessard (17) the prothallia and sporelings are restricted to places of little or no herbaceous growth. Very few non-woody plants were found near the patch on the above-mentioned slope, but, in this case, another limiting factor enters. Each year there is a considerable deposit of dead leaves, which tends to prevent the majority of the spores from reaching favorable depths in the soil. This may account for the lack of development of new colonies on this slope. Thus the species is spreading slowly by means of its rhizomes.

What has become of the ground pine which has been reported on First and Second Huckleberry Hills? The following explanations may account for the fact that it is not visible at the present time. Hunters, hikers, and picnickers frequently visit these woods. Through their carelessness fires spread over the slopes at various times. If this happens in the fall, the portion of the club moss which is above the ground is sufficiently dry to burn. If the plants are in fruit or beyond this stage the spores are destroyed because they contain oil, which causes them to be highly inflammable. If the fire burns the humus there is a possibility of the destruction of the fungi which are assumed to maintain the necessary symbiotic relationships with the prothallia and, also, of the subterranean gametophytes if they are developing sufficiently near the surface of the soil. If some of the spores and prothallia are not injured or destroyed, they are unable to develop because of the lack of sufficient moisture, due to the decreased amount of humus in the sandstone soil.

An examination of the weather records for a period of years does not show sufficient variation or decrease in precipitation to account, directly, for the death of prothallia or sporelings.

Since *Lycopodium* has become popular for Christmas decorations, man has collected the beautiful fan-like branches for commercial purposes. Upon request, this practice has ceased in this locality, but the period of time has not been long enough for the reappearance of the species.

Even if the conditions are favorable for the germination of the spores, the symbiotic relationships between prothallia and fungi have developed, fertilization has occurred, and the sporelings have started to break through the surface of the ground, the young plants may not survive if they are in an area which is too dry or receives too much sunlight. Such conditions are possible on the Huckleberry Hills due to the removal of trees for lumber or for fuel.

Still another important factor may influence the intermittent presence of *Lycopodium* sporophytes in the areas under observation. The germination of the spores and the growth of the prothallia and sporelings are very slow. No report was found concerning the time necessary for the production of the sporelings of *Lycopodium complanatum*, var. *flabelliforme*, but Bruchmann (5) found that 3 to 5 years are necessary for the germination of the spores of *L. Selago*, and an additional 6 to 8 year period for the maturation of the prothallia, i. e., a total of 9 to 13 years passes from the time the spores are deposited until the gametes are produced. Bruchmann (5) also found that 6 to7 years are necessary for the germination of the spores of *L. clavatum* and *L. annotinum*, and 12 to 15 additional years for the prothallia to reach sexual maturity. Assuming that comparable periods are necessary for *L. complanatum*, var. *flabelliforme*, it is possible that spores deposited several years ago by this species on the Huckleberry Ridges may be in the process of germination or the prothallia may be in some stage of development and at some future date *L. complanatum*, var. *flabelliforme* may be reported again in this particular habitat.

General Vegetation and Habitats. The dominant species are *Fagus grandifolia* and *Acer saccharum*. The most common secondary trees are *Quercus alba, Q. velutina, Q. rubra, Q. Prinus, Carya ovata, C. glabra, C. cordiformis, Fraxinus americana, F. quadrangulata, Ulmus americana, U. fulva, Morus rubra, Acer rubrum, Aesculus glabra, Liriodendron Tulipifera, Platanus occidentalis, Juglans nigra, J. cinerea, Celtis occidentalis, Prunus serotina, Tilia americana, Nyssa sylvatica*, and *Gleditsia triacanthos*.

The small trees occurring most abundantly are *Juniperus virginiana, Populus grandidentata, Carpinus caroliniana, Ostrya virginiana, Asimina triloba, Sassafras variifolium, Pyrus coronaria, Crataegus* sp., *C. punctata, Cercis canadensis*, and *Cornus florida*.

Of the subdominant species, the shrubs are the most conspicuous. Those which occur most frequently include *Salix nigra, Benzoin aestivale, Hydrangea arborescens, Ribes Cynosbati, Hamamelis virginiana, Rubus occidentalis, R. allegheniensis, Rosa setigera, Rhus copallina, R. glabra, Evonymus atropurpureus, Gaylussacia baccata, Vaccinium vacillans, Viburnum acerifolium, V. prunifolium*, and *Sambucus canadensis*.

Various species of ferns, such mosses as *Dicranum scoparium, Leucobryum glaucum,* and *Polytrichum commune,* lichens, and a liverwort, *Conocephalum conicum,* are the most frequent members of the cryptogamic societies.

As previously mentioned, the enumeration of the species cannot be included with this discussion. The majority of the herbs is omitted because their number is large.

On the sides of the steep, moist, shaded, V-shaped ravines, the most common species include *Phegopteris hexagonoptera, Adiantum pedatum, Asplenium platyneuron, A. angustifolium, A. acrostichoides, A. Filix-femina, Polystichum acrostichoides, Aspidium noveboracense, A. spinulosum, Cystopteris fragilis, Arisaema triphyllum, Uvularia grandiflora, Polygonatum biflorum, Laportea canadensis, Pilea pumila, Asarum canadense, Aristolochia Serpentaria, Polygonum scandens, Hepatica acutiloba, Stylophorum diphyllum, Iodanthus pinnatifidus, Cardamine pennsylvanica, Impatiens pallida, I. biflora, Sanicula canadensis, Thaspium aureum, Collinsonia canadensis, Galium circaezans, G. concinnum, Houstonia purpurea, Campanula americana, Eupatorium urticaefolium, Solidago caesia, S. latifolia,* and *Aster cordifolius.*

The old ravines are open, broad, and flat-bottomed. In the mouths or along the streams the species most frequently found, excluding the common trees and shrubs, are *Typha latifolia, Potamogeton* sp., *Salix nigra, Pilea pumila, Rumex obtusifolius, Polygonum acre, P. sagittatum, P. scandens, Phytolacca decandra, Penthorum sedoides, Impatiens pallida, I. biflora, Hypericum punctatum, Viola striata, Ludvigia palustris, Lysimachia Nummularia, Cuscuta Gronovii, Lappula virginiana, Nepeta hederacea, Lycopus uniflorus, Mentha spicata, Physalis pubescens, Echinocystis lobata, Lobelia siphilitica, Vernonia altissima, Eupatorium urticaefolium, Actinomeris alternifolia,* and *Erechtites hieracifolia,* in addition to the ruderals.

Camptosorus rhizophyllus, Trillium nivale, Aquilegia canadensis, and *Dirca palustris* were found only on the limestone ledges which occur frequently on the west-facing slope along North Pike.

Zones of Vegetation at the Head of the Lake. Before the building of the dam of the Bloomington Water Works, the bottom of this part of the Griffy Creek Valley was under cultivation. The dam was under construction from April, 1924 to March, 1925. As a result, a portion of the valley east of the dam, an area about one mile in length, is entirely flooded, and, as the water backs against the embankment at the east end of the lake, some of it passes under the bridge and up the creek for about one-eighth of a mile. On the east side of the bridge, the zones of vegetation from the north edge of the backwater, up the moderate, south-facing slope of Copperhead Ridge are very distinct. The most common species in each zone follow.

First Zone—Floating aquatics at margin of lake: *Potamogeton* sp. and algae.

Second Zone—Grasses, sedges, rushes, etc. These species grow in the mud just back of the water's edge: *Echinochloa crusgalli, Panicum dichotomiflorum, P. huachucae,* var. *silvicola, Muhlenbergia mexicana,*

Eleocharis obtusa, *Juncus acuminatus*, *J. tenuis*, var. *anthelatus*, *Polygonum pennsylvanicum*, and *Bidens frondosa*.

Third Zone—Cat-tail, sedges, etc.: *Typha latifolia*, *Cyperus strigosus*, var. *compositus*, *Scirpus pedicellatus*, *Salix nigra*, and *Solidago graminifolia*.

Fourth Zone—Ruderals, etc.: *Andropogon virginicus*, *Setaria glauca*, *Smilax hispida*, *Rumex crispus*, *R. Acetosella*, *R. obtusifolius*, *Polygonum pennsylvanicum*, *Lepidium virginicum*, *Potentilla monspeliensis*, *P. canadensis*, *Geum canadense*, *Trifolium pratense*, *T. repens*, *T. hybridum*, *Melilotus alba*, *Desmodium Dillenii*, *Strophostyles helvola*, *Oxalis corniculata*, *Acalypha virginica*, *Euphorbia Preslii*, *Hypericum mutilum*, *Oenothera biennis*, *Gaura biennis*, *Daucus Carota*, *Steironema lanceolatum*, *Apocynum cannabinum*, *Asclepias incarnata*, *A. syriaca*, *Ipomoea hederacea*, *Cuscuta arvensis*, *Verbena urticaefolia*, *Prunella vulgaris*, *Hedeoma pulegioides*, *Solanum nigrum*, *Plantago Rugelii*, *P. lanceolata*, *P. aristata*, *Lobelia siphilitica*, *Vernonia altissima*, *Eupatorium perfoliatum*, *E. urticaefolium*, *Solidago nemoralis*, *S. altissima*, *Aster cordifolius*, *A. dumosus*, *A. ericoides*, var. *villosus*, *Erigeron canadensis*, *Gnaphalium polycephalum*, *Ambrosia trifida*, *A. artemisiifolia*, *Xanthium canadense*, *Helianthus tuberosus*, *Achillea Millefolium*, *Chrysanthemum Leucanthemum*, *Erechtites hieracifolia*, *Lactuca floridana*, and *Hieracium scabrum*.

Fifth Zone—Shrubs, small trees, and lianas: *Rubus allegheniensis*, *Rhus glabra*, *R. copallina*, *Salix nigra*, *Ulmus americana*, *Liriodendron Tulipifera*, *Sassafras variifolium*, *Liquidambar Styraciflua*, *Platanus occidentalis*, *Cornus florida*, *Fraxinus americana*, *F. pennsylvanica*, *Smilax hispida*, *Rhus Toxicodendron*, and *Vitis aestivalis*.

Sixth Zone—Secondary and climax trees. These species have been given in the discussion of the general vegetation and need not be repeated. The ferns growing on the slope are *Asplenium platyneuron*, *Polystichum acrostichoides*, and *Botrychium obliquum*.

The plants growing along the upper portion of Griffy Creek, along roadsides, and in the woods on the surrounding ridges and slopes have been the source of the propagative structures which have produced these vegetative zones.

The chief agents of dissemination of the plants in the first three zones have been water, birds, and wind. The latter has also played an important part in disseminating the species of Compositae. Approximately one-third of the plants in the fourth zone belong to that family. The number of plants belonging to each species of this family is much larger than that of any other species on the slope. Many squirrels and birds live in and among the trees and shrubs. These animals and the wind are responsible for scattering the seeds and fruits of the woody plants upon Copperhead Ridge.

Hydrarch Succession in a Solution Pond. Rogers Hill is 940 feet above sea level, the highest point in the area selected for this study. Figure 1 shows the exact location and the rock formations of this hill. The presence of Mitchell limestone capping the hill indicates at once the origin of this sink hole or the Hill Pond, as it is commonly known.

Since Scott (13) has discussed in detail the geology of this sink hole, the writer will only briefly review the chief steps in its formation.

Mitchell limestone is rather impervious and contains numerous vertical joint-planes. Originally this sink hole was probably a funnel-shaped cavity in the rock and collected the water which drained from the crest of the hill about 16 feet above it. The pond is located south of the east end of the Indiana University Reservoir and a few rods southwest of the summit of the hill. Mitchell limestone favors the development of sink holes, because the carbonated meteoric water dissolves the almost pure limestone as it percolates through the joint-planes instead of being absorbed by the rather impervious rock. This passage of water continues as long as there is an outlet into the other stone beneath it. But at some stage this outlet may become obstructed and then the sink hole is a pond. Such is true in this particular case. The accumulation of silt and plant débris in the bottom of the obstructed funnel leads to the destruction of the pond.

The history of the Hill Pond since 1887 is known. Scott (13) states that it was eight or nine feet deep at that time; that in 1910 it was 46 inches in depth, 70 feet in length, and 57 feet in width; and that a narrow zone of grass, *Bidens,* and *Carex* surrounded the pond. In his paper he lists the algae which grew there in 1910. *Closterium Dianae* Ehrb., *Cosmarium Botrytis* Menegh., *Spirogyra majuscula* Kuetzing, *Oedogonium undulatum* (Bréb.) A. Braun, and *Chaetophora pisiformis* (Roth) Ag. occurred commonly, and *Cosmarium tetraophthalmum* (Kg.) Bréb. and *Docidium crenulatum* (Ehrb.) Rab. were found rarely. *Zygnema stellum* Ag. was collected on two occasions. He continues to say that "*Typha latifolia* L. is the most conspicuous plant in the pond. It covered the shallower two-thirds of the pond in 1908 and has since increased to about three-fourths of the total area. *Alisma Plantago-aquatica* L. occurs sparsely at the margin of the pond. *Veronica Anagallis-aquatica* L. covers the bottom between the *Typha* stalks on the north and east sides of the pond."

The author has been informed by a student of the plankton in 1914 that at that time there was a margin of *Typha latifolia* and the remainder was covered with floating aquatics, such as *Lemna, Wolffia,* and *Ricciocarpus.*

On October 25, 1927, and February 3, 1928, the writer visited the pond. On the former date the pond was dry, and the species of plants were noted. On the latter date measurements were taken, every 10 feet, when the pond was covered with ice to a depth of four to five inches. The maximum width is now 51 feet, length, 66 feet, and depth, 27 inches at the upper surface of the ice. Comparing with Scott's data of 1908 to 1910, there is a difference of four feet in the length, six feet in width, and 19 inches in depth. This variation in dimensions is the result of the accumulation of silt and plant débris over a period of 20 years, and of drainage. A ditch has been dug in the southwest part so that the water is lowered to its present level, the overflow passing down the slope.

Zygnema stellum Ag. is abundant at the north end of the pond and extends into the center. The water in which it grows varies in depth from 9 to 25 inches. *Typha latifolia* is scattered through the central portion of the pond and extends to within three feet of the edge of the water. *Echinochloa crusgalli* accompanies *Typha latifolia* in the shallower portions and forms a zone between the area occupied by *Typha* and the margin in some parts of the pond. The depth of the water in which the cat-tail stage is dominant varies from 12 inches on the east side of the pond to 27 inches in the northwest part. As noted above this is the deepest place in the pond and occurs about 11 feet from the water's edge. On the east side, extending in a southwestward direction, is a zone of *Cephalanthus occidentalis* six feet wide and nine feet long. The water is nine inches deep at the inner extremity of the zone.

No margin occurs at the north end, but one extends around the remainder of the pond and reaches a width of approximately 8 to 14 feet on the sides and at the south end. Its absence in the northern portion is due to the attempts of the landowner to excavate the pond. At one time the farmer wished to drain the pond to keep stock and students away from it. At another time he desired to rid the pond of all vegetation in order to supply his cattle with water. In either case, the plant succession is influenced considerably. The following are the most common plants in the marginal zone: *Polygonum pennsylvanicum, Acalypha virginica, Ambrosia artemisiifolia,* and *Bidens frondosa.*

The chief agents bringing reproductive bodies and vegetative portions of plants to the solution pond are wind and animals, especially water birds. They fly from one body of water to another, carrying plant parts in the mud which adheres to their feet.

The stages in the hydrarch succession in the Hill Pond from 1887 to 1927 have occurred in the following order, although two or more may have existed at the same time: (a) alga and duckweed, (b) cat-tail, (c) sedge and grass, and (d) shrub. The normal succession has been and is still being disturbed by excavation and drainage.

Summary. This is the first of a series of studies the author has planned concerning the phytoecology of southern Indiana and includes a study of (a) distribution of *Gaylussacia baccata* and *Vaccinium vacillans* in a limestone area of the Bloomington Quadrangle, Monroe County, Indiana, (b) plants which are indicators of soil acidity in this specific locality, (c) *Epigaea repens* and *Lycopodium complanatum,* var. *flabelliforme* as glacial relics, (d) general vegetation and habitats, (e) vegetation zones at the head of the lake, and (f) hydrarch succession in a solution pond. The part of Monroe County considered in this study lies in the driftless part of Indiana, and the surface rocks of the area belong to the subcarboniferous or Mississippian Period.

Before *Gaylussacia* and *Vaccinium* can grow naturally in this limestone area it seems to be necessary for leaching and erosion to occur. These processes remove sufficiently the lime carbonate. In the absence of its neutralizing influence the inorganic and organic acids cause the soil to be sufficiently acid for the growth of these plants. In this locality, the huckleberries and blueberries commonly grow in sandstone

soil which has a pH value of 4.4. If the factor of erosion is too strong, these shrubs are removed from the slopes because their roots are imbedded shallowly in the soil. *Gaylussacia* and *Vaccinium* occur in a xerarch succession and are preceded commonly by lichens, *Dicranum scoparium, Leucobryum glaucum, Polytrichum commune, Danthonia spicata, Carex picta,* and *Mitchella repens.*

The following species of plants have been found to be indicators of acid soil in this specific area: *Dicranum scoparium, Leucobryum glaucum, Polytrichum commune, Lycopodium complanatum,* var. *flabelliforme, Danthonia spicata, Carex picta, Michella repens, Monotropa uniflora, Epigaea repens, Pedicularis canadensis, Gaylussacia baccata, Vaccinium vacillans,* and *Viburnum acerifolium.*

Epigaea repens and *Lycopodium complanatum,* var. *flabelliforme,* are out of their natural range in southern Indiana. As the glacial ice advanced, these plants grew in the tundra, and as the ice retreated, they remained in suitable habitats. These glacial relics are surviving the competition with other plants but are not spreading noticeably at the present time.

The area under study is a part of the climax forest. The dominant trees are *Acer saccharum* and *Fagus grandifolia.*

The zones of vegetation on the south-facing slope of Copperhead Ridge indicate the most common species and the stages in the secondary succession which may occur at the head of the lake providing the sere is undisturbed.

Additions have been made to the record of plant succession in the solution pond on Rogers Hill, the history of which has been known since 1887.

The writer wishes to express sincere thanks and appreciation to Dr. D. M. Mottier for the valuable suggestions and criticisms so kindly given concerning this study.

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BARK FORMATION.

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A large sweet apple-tree of the Golden Sweet variety located about one mile north of Bloomington, Indiana, and recently cut down was remarkable in three ways.

The first of these was its enormous size, especially as regards its diameter. The height of this tree did not exceed that of some other apple trees, for it was not more than 40 feet tall. This height is sometimes attained by the "Scarb Apple" tree. Its diameter, however, was six feet. This is very exceptional for any kind of apple trees. Taking into consideration its age, its increase in diameter had averaged somewhat more than an inch each year.

A second unusual feature was its huge top or crown. Some distance above the ground the gigantic trunk divided into three large branches or divisions. As these spread apart they produced an enormous crown 70 feet in diameter, thus presenting a striking appearance. In the large main trunk, above referred to, a large cavity had formed which was about five feet long and which averaged about four feet in diameter. From the cavity to the outside the shell of the trunk was therefore, on the average, about one foot in thickness, except in the three places to be mentioned later. Throughout the shell of the trunk there was continuous active wood.

The third interesting fact concerning this tree was that the large cavity contained on its periphery three strips or regions of bark similar to the bark on the exterior of the trunk. Some bark, as is often the case, was produced interiorly by the edges of the trunk bordering the cavity, curving inward in such a fashion and to such a degree that the region of bark producing cells were turned completely to the interior. The three strips of bark were produced at the three places in the cavity where the wood was perfectly sound, but very thin in proportion to the rest of the tree trunk's thickness. No rifts extended or had extended from the interior to the exterior at these points. The three strips of bark thus interiorly located were, in each instance, about three feet long. Each was of very limited width, varying from one to four inches. However, each strip grew vigorously and was as thick as the bark on the exterior of the trunk. The wood of the shell of the trunk decreased from about one foot to one-half inch in thickness where the three layers of interior bark were formed. This sudden decrease in thickness, which occurred mostly from the inside, but also to an extent from the outside caused the bark forming cells to be kinked sharply out of line by interior and exterior growth. While partly maintaining their identity on the exterior a division of the phellogen layers occurred at the thin places and were thereby directed at the edges interiorly at these places.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

The bark producing cells and bark were formed across the thin and narrow strips of living wood on the interior in the same manner as on the exterior of the wood. The subsequent divisions of the bark-forming cells bridging these thin places were as active as those on the exterior side of the wood and therefore produced equally thick bark. This interior formation of bark should not be confused with those cases of bark formation from the edges of a wound. It is also different from those instances in which parts of hollow tree trunks at times die and decay away entirely through the trunk leaving longitudinal peripheral strips varying in length from a few inches to many feet. If there is a living center of tissue unaffected by the decay process, then subsequently or even simultaneously at points along the strip, the formation of bark may often commence or may continue what may already be present. In this way strands or strips may stand apart from the main trunk and thus be partly or completely surrounded by bark by encroachments from the edges.

VARIATIONS IN ERIGERON ANNUUS.

F. M. ANDREWS, Indiana University.

During the summer of 1924 the writer observed an unusual number of variations or deviations from the usual form in the flowers and mode of branching in various representatives of the Compositae. Among the most striking of these deviations were observed in the common *Erigeron annuus* growing in Monroe County, Indiana. Instances of variation were observed to be unusually numerous as compared with previous seasons. A few specimens of *Bidens bipinnata* also showed deviations.

Extreme variation in the height of the plants of Erigeron in the same locality and the same soil and light condition was very evident. Specimens varying from 1 dcm. to 25 dcm. were occasionally found within one square meter.

The flowers of many of the specimens were normal. Some of the plants, however, showed considerable difference in the flowers. First to attract attention in this respect was the number of rays. In some plants the number of rays was much reduced, being only about half those usually present, while in other specimens the rays were more nearly the usual number. The color of the rays was normal as was also the size and form in most instances. The rays, however, of some of the flowers were considerably shorter than those in normal heads.

The changed appearance of the stem of *Erigeron annuus* was the thing which first attracted my attention in these plants even from a distance. The flower heads in certain specimens became fewer and fewer and finally disappeared altogether. A large number of such plants produced on the stem nothing but a mixture of branches and leaves in great profusion. Other plants produced only leaves on the single stem. Both branches and leaves were formed in such number

that the stem resembled a clavate brush, or cylindrical brush and in some cases approached a moniliform appearance. Where branches were formed they were short. The leaves varied in size from the normal to many which were almost filiform, and were scattered among the normal leaves from the commencement of leaf formation to the tip of the stem. In most of the plant showing the abnormal condition the large leaves were different as to margin also. The larger of these leaves, in many of the plants, were normal as to size and shape. Most of them were entire. The others on the same specimen were coarsely and sparsely serrate. The writer has also observed this same transformation in Erigeron of the Indiana Sand Dunes though less pronounced, and plants of this species also sent me from Illinois. A somewhat similar condition sometimes produced traumatically should not be confused with the above mentioned state which in some cases is due to a more or less diseased condition. One specimen was observed in which a healthy normal stem of Erigeron was attached at the base to an abnormal stem which was equally vigorous but with the otherwise changed appearance as above described. In some specimens fasciations in the form of extraordinary stem flattening was evident. Monstrosities in Trillium and other plants, in some instances decidedly change the appearance of the plant as described in this paper.

A NATURAL PROOF THAT THE ROOT TIP ALONE IS SENSITIVE TO THE GRAVITATIONAL STIMULUS, II.

F. M. ANDREWS, Indiana University.

In the Proceedings of the Indiana Academy of Science for 1905 the writer contributed a paper showing that the root-tip alone perceives the gravitation stimulus. This was ascertained not by means of the glass-cap experiment as was successfully performed by Czapek, but as a result of the accidental and central breaking of the scutellum and its adherence in a firm and solid mass to the root-tip. In addition the coats of the grain remained attached to the separated mass of tissue about the root-tip and formed therefore an enclosure so strong that the root-tip was unable to free itself. The root-tip thus covered by this firm mass extended 3 mm. back from the tip, which in my specimens reached to the center of the embryo. The mass weighed 15 mg. The region of gravitational perception was thus completely covered and when placed horizontally showed no response to gravity. The grains of corn had been soaked and planted vertically as regards their long axis in a mixture of sifted and properly moistened beech and maple saw-dust.

Since 1905 the writer has observed and studied five other exactly similar specimens of *Zea mais*, which were accidentally discovered and which carried masses of tissue about the root-tip as above described. The occurrence of such a covering, as mentioned here, is therefore com-

paratively rare. It is not to be mistaken for those instances in which at times a certain amount of tissue may adhere as small local masses, as sometimes occurs laterally on the root of *Zea mais*. These specimens were all, as above stated, from vertically planted grains of *Zea mais*, as regards their long axis. Of the many thousands of seedlings grown for other experiments the five specimens reported here were the only ones showing the peculiarly enclosed root-tips mentioned, and were therefore of accidental occurrence. All of these seedlings had been grown in sawdust.

Attempts were made with many soaked grains of *Zea mais*, as well as with a large number of grains that were just ready to germinate, to cut the scutellum and testa in such a manner as to produce the mass of tissue about the root-tip as above described. These experiments were unsuccessful and after many such experiments, further trials were abandoned entirely. The root in each case had curved somewhat so as to approach the back of the scutellum, but as in my first experiments even this curvature allowed the mass of tissue to be easily removed or replaced. These cap-like masses were quite firm and strong enough to prevent the root, during the time of experimentation, from breaking them. The root was not damaged by them in any way and, since each of these tissue masses only weighed from 14 to 18 mg., their weight was too small to be of influence as regards the points at issue here.

Experiments were also performed with glass tubes at the same time on other seedlings of *Zea mais*. These glass tubes were about 3 mm. long and weighed from 30 to 40 mg. which weight should not be exceeded. These tubes were closed at one end and each arm had a length of 1.5 mm. as in my former experiments and in those of Czapek. The difficulty of making these tubes properly is very great. They must fit the root in a suitable manner. Equally necessary is the great care that must be exercised so as to avoid injuring the roots. In order to get the small weight required, narrow thin walled glass tubing was properly heated and drawn out to the same internal diameter as the root so as to fit it exactly, but not too tightly. It should then be bent at right angles, care being taken to avoid flattening at the curve. The tubes should then be carefully sealed at one end without contracting the closed arm to a smaller diameter than the root and without allowing an undue accumulation of glass at the closed end. It is advisable to leave a small pore or opening near the closed end which, however, should be very narrow. The open end should be slightly rounded by heating so as to avoid cutting the root when adjustment is made. Imperfectly made glass-caps have been the cause of many failures by different investigators in this study or have led to incorrect conclusions. This is the reason for the failures of Wachtel and Richter. The writer has tried various substances for making the caps for the roots of *Zea mais*, but none of these have served the purpose so well as glass.

There is no possibility, as Nemec seems to assume, that the geotropic perception might lie in the root-cap. It must lie in the apex of the root since certain roots do not possess a root-cap. Even in those roots which possess a root-cap for a time, this is dispensed with later, and therefore

cannot be the region of gravitational perception. Where such a temporary root-cap is removed at first, the root perceives the gravitational stimulus just the same, so the root-cap in this case perceives no stimulus. The root-cap can also be removed mechanically and the root perceives the geotropic stimulus just the same. The same holds true of roots which normally possess a permanent root-cap, for in some cases such permanent root-caps may be removed by proper care, without great injury to the root tip. Nevertheless, here also the root-apex perceives the geotropic stimulus and responds in the normal way. The experiments of Piccard do not prove the points under consideration here and his investigations are open to question. In addition, the idea that the cotyledon apex is instrumental in geotropic perception in some of the Gramineae needs further study.

The masses of tissue above mentioned could be removed from the roots without damage if care was exercised. The root-tip then perceived the gravitational stimulus in the usual way and with normal speed and conduction. But as long as the mass of tissue remained on the root no response to gravity was possible. The roots with these masses of tissue were subjected to the same experiments described in my former paper on this subject and such as Czapek carried out with glass-caps. The rate of growth in the roots encased by these masses of tissue, as well as those roots that were enclosed in the glass-caps, was nearly as rapid as in roots of the controls which were entirely free. The danger of injury that the glass-cap method often occasions was eliminated by the masses of tissue which in some cases were present. Although these masses of tisue were of accidental occurrence, they nevertheless furnished a natural method of proving in perhaps even a better way what has been successfully demonstrated by the use of glass-caps, namely, that the apex of the root is the region of perception of the stimulus of gravity.

STUDIES ON POLLEN, IV.

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As this investigation of the pollen of various plants has progressed, new and improved methods and apparatus have been devised and used. The large number of plants studied and the many cultures made from each required more elaborate and rapid methods and for the sake of accuracy, arrangements which would provide uniform conditions. The old method of using paper cells, while effective, was soon discarded for the glass ring cell. These rings were conveniently attached to slides by means of paraffin. They had the advantages over the first form, that they could be conveniently and individually darkened or illuminated for certain investigations; would prevent desiccation; were somewhat more rapid and were less liable to accident. These glass ring cultures, however, involved more expense and were liable to the same lack of uni-

formity of growth conditions as the paper cells, unless special provisions were made. The gas chamber method made possible various experiments not possible by either of the two methods just mentioned and also was a convenient way of studying by transfer of cover glass cultures to the gas chamber used, a large number of cultures in rather rapid succession. But these methods in all cases involved a large amount of work for each culture made, as well as a considerable expenditure of time and occasionally, uncertainty as regards uniformity of conditions.

The difficulties here mentioned were conveniently and effectively removed by using properly constructed petri dishes about 10 cm. in diameter and 12 mm. deep. In the bottom of this dish was placed a layer of distilled water about 2 mm. deep. Near the periphery of the lid and on the outside was placed at regular intervals the designations of the ten solutions used. These were distilled or tap water, and sugar in the following percentage: 1, 5, 10, 15, 20, 30 40, 50, and 60. The designations of the solutions on the outside may be made with pencil; or very quickly and conveniently with hydrofluoric acid.

These designations should be made in very small, thin letters so as not to interfere with the observation of the specimens. The lids of most petri dishes are too thick for observation with ordinary high powers, but are thin enough for observation and counts with many of the so-called low powers of the microscope, which are ample for much of the study. The lids of some petri dishes were bored with holes one cm. in diameter and a cover glass used on these. The risk of breakage in so doing even with proper machinery is great, but considerable success was experienced. Better than this a large thin sheet cover glass for the entire dish may be used in place of the usual lid. This will then allow the use of ordinary high powers for more minute study. This lid should be provided with checks to prevent movement on the dish. In case such a large thin cover glass is not at hand and where observation with high powers is desirable, very thin cover glasses may be placed on each of the ten cultures on the lower side of the ordinary lid when this is inverted. This will thus allow direct observation of each culture with high powers when the lid is removed from its base and inverted on the stage of the microscope and for longer or shorter periods of time according to the arrangements for moisture. When such study is completed the lid may again be placed in the usual position on its base. Unless great care is used a troublesome feature of this study is condensation. This can be prevented by keeping all the pieces of apparatus at the same temperature. To do this the glass-ware, tools and other things used should be placed in a thermostat at the desired temperature long enough to acquire a constant temperature before the experiment is commenced. A Molisch freezing-box in which warm water of the desired temperature is used is convenient for the microscopical observation when properly arranged. A constant temperature room is also very convenient in this study if properly adjusted. One of the most convenient and accurate heat controlling arrangements for the cultures on the stage of the microscope is an electric cell similar to one I have constructed and described elsewhere.

The petri dish method has proved to be the most convenient of all the methods thus far adopted. It is more rapid and has the additional advantage of placing a whole series of cultures, aside from the nature of the solutions used, under precisely the same conditions. I have investigated to date the pollen from 705 different species of plants both wild and cultivated. Both tap and distilled water were used and in addition nine different solutions of sugar above mentioned. The longevity and the time required for germination were determined. It is necessary to make fresh solutions of sugar at frequent intervals. The pollen was mounted so that some of the grains were submerged and others were well moistened. In these two cases some of the submerged pollen at times did not grow, whereas the pollen on the surface or just moist did grow.

The pollen of eleven of the 705 plants studied produced two or more tubes. The pollen which germinated most quickly was that of *Scabiosa atropurpurea* and the next were *Asphodeline lutea* and *Tradescantia virginica*. The largest pollen grains were those of *Mirabilis Jalapa* which were .25 mm. in diameter, while among the smallest were those of *Myosotis Scarpoides* which measured on the average .003 mm. in diameter. The pollen grains of *Nelumbo lutea* were also extremely small and were no larger than the very narrow pollen-tube which they produced. In number, the variation is very great. In *Mirabilis Jalapa* there are on the average only about 32 pollen grains in each anther cavity, while in others, as in certain representatives of the Boraginaceae, there are many thousands in each anther cavity. Thus *Borago officinalis* may have as many as 60,000 in an anther cavity according to Kerner. The pollen-tubes of *Scabiosa atropurpurea* were four in number and very short. Other pollen-grains such as those of *Verbena fructicosa* merely commence to germinate in certain solutions. Part of the pollen of one plant, *Vaccinium stamineum*, germinated in some cases in the anther cavity. Other pollen-tubes, such as those of *Tritonia crocosmaeflora*, *Sinningia speciosa*, and *Torenia asiatica*, germinate readily in sugar solutions and in certain strengths grow so rapidly that the advancing tube may be seen with the microscope when only moderate magnification is used. In addition Tritonia may, as Strasburger points out, occasionally form cross-walls in the pollen tube. What occurs in this respect when the pollen of Tritonia germinates on its own stigma opens up a point for inquiry. In sixteen of the 705 plants experimented with, 85 or more pollen grains per hundred germinated in certain of the solutions used. The pollen of *Tradescantia virginica* grown in the shade showed better growth than the pollen of this plant when it was grown in direct sunlight.

OBSERVATIONS CONCERNING DISEASES OF IRIS AND TULIPS.[1]

E. B. Mains, Purdue University Agricultural Experiment Station.

The season of 1928 was very favorable for the development of diseases among ornamentals at Lafayette, Indiana. Especially during the period of blossoming of iris and tulips, considerable rainy weather occurred. As has been previously noted[2], a garden of ornamental plants with its variety of species under more or less intensive cultivation offers unusual opportunities for the development of a large number of diseases. In the writer's garden, nearly all of the major diseases of iris, soft rot, leaf spot, sclerotial rot and rust occurred, and the principal disease of tulips, botrytis blight or fire disease, was especially virulent.

Iris Diseases.

Soft Rot. The soft rot of Iris is generally considered as caused by *Bacillus carotovorus*. Richardson finds that it differs slightly from the typical *Bacillus carotovorus* and it may be a special form of this species. *Bacillus carotovorus* causes a soft rot of a wide variety of plants such as carrot, cabbage, cauliflower, turnip, rutabaga, lettuce, cucumber, muskmelon, potato, tomato, pepper, egg plant, hyacinth, onion, etc. In the writer's garden it caused a severe rot of carrots in 1927.

In 1928, it was first noted on iris about blossoming time. Infection usually occurs either in the rhizome or at the base of the leaves. Attention is usually first attracted to the disease by the occurrence of leaves which show wilting at the tips. The bases of such leaves show considerable areas with a water soaked appearance (fig. 1). As the disease progresses, the rot develops up the leaf blade. In this way whole fans may rot off at the base, fall over, and die (fig. 2). The infected portion is reduced to a soft slimy mess. In a similar way the flower stalks may be invaded. The rotting and collapse of the tissue of the lower part of the stalk finally causes it to break over. In the rhizomes, the rot often affects only a portion of the clump. The rhizome is reduced to a soft slimy mess except for the persistent epidermis. Eventually the interior of the rhizome dries up, changing into a granular brown powder surrounded by the persistent epidermis. The rotting plants have a strong unpleasant odor resembling decaying flesh.

The way in which infection occurs is not clear. Probably infection occurs through any wound. In 1928 a whole clump of an unknown

[1] Contribution from the Department of Botany, Purdue University, Agricultural Experiment Station.

[2] Mains, E. B. Plant Diseases in a Home Garden. Proc. Ind. Acad. Sci. 37:341-353. 1928.

Fig. 1—Soft Rot of Iris. Fans showing infection at the base. These leaves were rapidly reduced to a soft, slimy, ill-smelling mess.

variety of the Germanica group died. An examination showed that this was due to a combination of borer infestation (fig. 3) and soft rot, the rot probably entering through the wounds caused by the borer. This was usually the case when infection occurred in the beardless Iris. In every instance where rot occurred in an Iris of the beardless groups, it was associated with borer infestation. Such was not usually the case in varieties of the bearded Iris. An examination of the clump illustrated in figure 2 showed no evidence of borer attack. It is probable that any injury may open the way for infection. The prevalence of the organism and its omnivorousness account for the wide distribution of the trouble.

During 1928 a clump of the Germanica type so commonly grown in gardens a generation ago was completely rotted. Of the bearded Iris the varieties, Blue Jay, Nibelungen, Quaker Lady, Queen Caterina, and Purple King were most severely infected. A number of bulbs of the variety Rosa Bonheur, an English Iris, were completely destroyed. The species *Iris laevigata, I. spuria, I. halophila, I. setosa* showed considerable rotting associated with borer infestation. Although a number of varieties and species showed no infection, no conclusion can be drawn concerning relative susceptibility since such plants probably were not exposed to infection.

Fig. 2—Soft Rot of Iris. Clump showing several fans rotted off and broken over in the foreground.

Very little is known concerning the control of this disease. The control of insects attacking the rhizomes will probably help to reduce this disease. For this reason, burning during the winter of all plant debris and weeds which harbor the eggs of the Iris borer is to be recommended. If the rot of the rhizome has not progressed too far it may be controlled, according to Hoare, by digging infected plants, cleaning away the rotted portion and then dipping in a pink solution of permanganate of potassium. The plants should then be reset in a new location which has received a dressing of lime. A number of the organic mercury compounds which are now on the market are probably well worth trying, both for the treatment of diseased rhizomes and infected soil.[3]

[3] Hoare, A. H. Iris Diseases. Jour. Min. Agr. Great Britain **32**:454-458. 1925. Soft Rot p. 457.

Richardson, J. K. A Study of Soft Rot of Iris. Ann. Rep. Quebec Soc. Prot. Plants. **15**:105-121. 1922-1923.

Van Hall, C. J. J. Das Faulen der junger Schlosslinge und Rhizome von Iris florentina und Iris germanica, verursacht durch einige andere Bacterienarten. Zeit. f. Pflanzenkrank. **13**:129-144. 1905.

Fig. 3—Soft Rot of Iris. Borers often afford entrance for the disease. This clump was almost completely destroyed by it. Note the borers among the rotting rhizomes.

Sclerotial Rot. This disease has usually been referred to as *Sclerotium Rolfsii.* A culture of the organism sent to Prof. H. H. Whetzel in 1927 was determined by him as *S. Delphinii* Welch. In a letter Professor Whetzel states that "It is certainly not *S. Rolfsii.* That species does not in my opinion occur as far north even as Lafayette, besides the sclerotia are too large for *Rolfsii.*"

This disease attacks principally the base of the leaves. Attention is usually attracted to the disease by leaves showing brown tips. When this is caused by Sclerotium (several diseases may produce a similar effect) the base of the leaves and the rhizome are covered with the white mycelial growth of the fungus on which numerous light brown sclerotia occur. As the disease progresses the leaf bases collapse and the leaves fall over on the ground and die. They usually become covered with the mycelium and sclerotia of the fungus. In the writer's garden, this disease has not been specially destructive. The damage has been limited to leaves destroyed and in most cases, only a relatively few leaves are killed. This disease, however, is undesirable, since it not only will reduce the vigor of the plants if operative over a period of years but it makes the plants unsightly.

In 1928 the disease was most severe on the varieties Lent. A. Williamson, Blue Boy, Dalila, and Pallida Dalmatica. The varieties Othello, Mithras and Albert Victor were moderately infected and Her Majesty, Dorothea K. Williamson, Blue Jay and Violacea grandiflora showed a slight infection. It is doubtful if this represents differences in relative susceptibility. To obtain information concerning varietal susceptibility to this disease it will be necessary to study varieties under conditions of uniform infection.

Very little is known concerning the control of this disease. Sulphur is apparently of little effect. In 1927 severely infected plants of the variety Pallida Dalmatica were divided and part of the divisions dusted with sulphur and planted in a new location. In 1928 this showed as much infection with Sclerotium as those which were not treated. The organic mercury compounds are well worth trying. It would be desirable to treat both the rhizomes and infested soil with these.

Leaf Spot. This disease is caused by the fungus *Didymellina Iridis (Heterosporium gracile)*. It is first noticeable as yellowish spots, which finally are surrounded by a brown margin. The whitish center finally becomes more or less covered with the black conidiophores and spores. As the infection spreads the spots coalesce and finally the leaves are entirely killed. This disease is seldom of such severity that plants are killed. The defoliation over a period of years probably reduces the vigor and multiplication of the plants and may accentuate winter-killing in the case of the less hardy varieties. The unsightly condition produced by the dead leaves is also very undesirable in an ornamental plant.

Early in the spring of 1928 all of the dead leaves of Iris varieties were removed and destroyed, following the recommendation of Tisdale. This resulted in much less of the disease during 1928. It did not appear in any amount until late in the summer. By late fall, however, it had reached a moderate development on susceptible varieties. The varieties Florentina alba, Monsignor, Fairy, Ballerine, Queen Caterina, Queen Alexandra, Quaker Lady, Violacea grandiflora showed only a slight infection. Sherwin Wright, Mrs. Neubronner, Lent. A. Williamson, Loreley, Dr. Bernice, Her Majesty, Parc de Neuilly, Purple King, Madame Chereau, Flavescens, Aurea, Rhein Nixe, Parisana, Lohengrin, Gypsy Queen, Mithras and James Boyd showed a fair amount of infection. Blue Jay, Jacquesiana, Lohengrin, Mrs. Darwin, Iris King, Mary Garden, May Queen, Storm Cloud, Honorable, and Nine Wells were moderately infected. Of the species *Iris dichotoma* and *I. tectorum* showed a slight to moderate infection. *Iris versicolor, I. halophila, I. pumila cyanea, I. siberica, I. fulva, I. pseudacorus, I. xiphium, I. xiphioides, I. Kaempferi, I. lacustris, I. cristata, I. orientalis, I. ensata, I. Bulleyana, I. setosa,* and the variety Dorothea K. Williamson showed no infection.

As mentioned above, Tisdale recommends the destruction of dead leaves in early spring. The fungus lives over winter in the dead diseased leaves and spreads from these to the young leaves in the spring. Such leaves should be destroyed before new growth starts. Some growers practice burning over their beds during the first dry period in the spring. This should be done before growth starts. The dead leaves should be dry and there should be enough wind so that the fire will travel rapidly over the plants without injuring the shallowly planted rhizomes and buds. Hoare states that vigorous plants are less likely to attack and recommends fertilizing with lime and phosphates.[4]

[4] Hoare, A. H., Iris Diseases. Jour. Min. Agr. Great Brit. 32:454-458. 1925. Leaf Spot p. 455.

Tisdale, W. B. Iris Leaf Spot Caused by Didymellina Iridis. Phytopath. 10:148-163. 1920.

Rust. The rust of Iris was introduced into the writer's garden in 1928 for the purpose of obtaining data concerning the relative susceptibility of the various varieties and species in connection with a detailed study of this disease. This disease is caused by *Puccinia Iridis*. On susceptible varieties abundant brown uredinia are produced (fig. 4), and if the infection is severe the leaves are finally killed. This disease probably is seldom very destructive. Like leaf spot and sclerotial rot it weakens infected plants and makes them unsightly. In North America this rust has been collected on *Iris Douglasiana, I. fulva, I. longipetala, I. missouriensis, I. tenax, I. tuberosa, I. versicolor, I. xiphium* (Arthur & Fromme, North American Flora 7:379). In addition, it has also been listed as occurring in other countries on *I. aequiloba, I. caucasica, I. decora, I. dichotoma, I. ensata, I. filifolia, I. flavescens, I. flavissima, I. florentina, I. foetidissima, I. fumosa, I. fuscata, I. germanica, I. gracilis, I. graminea, I. Hartwegi, I. iberica, I. Kingii, I. ochroleuca, I. Pallasii, I. pallida, I. pseudacorus, I. pseudopumila, I. pumila, I. ruthenica, I. spuria, I. tectorum, I. xiphium*, and *I. xiphioides* (Sydow Monographia Uredinearum 1:598-600. 1904). During 1928 the rust infected *I. halophila, I. xiphioides* (Royal Blue), *I. Missouriensis*, and *I. setosa* (several plants) severely. *I. dichotoma, I. spuria, I. lacustris, I. versicolor* (few plants), *I. setosa* (several plants), and *I. Bulleyana* were moderately resistant. *I. ensata, I. stylosa, I. graminea, I. pseudacorus, I. orientalis, I. sibirica, I. tectorum, I. versicolor* (several plants), *I. fulva*, and *I. Kampferi* either showed no signs of infection or a slight brown flecking. Of the bearded Iris none of the varieties showed any sign of infection. The varieties Mrs. Neubronner, Iris King, Mrs. Darwin, Lent. A. Williamson, May Queen, Nine Wells, White Knight, Gypsy Queen, Perfection, Honorable, Blue Boy, Sherwin Wright, Storm Cloud, Mary Garden, Loreley, Dr. Bernice, James Boyd, Her Majesty, Mithras,

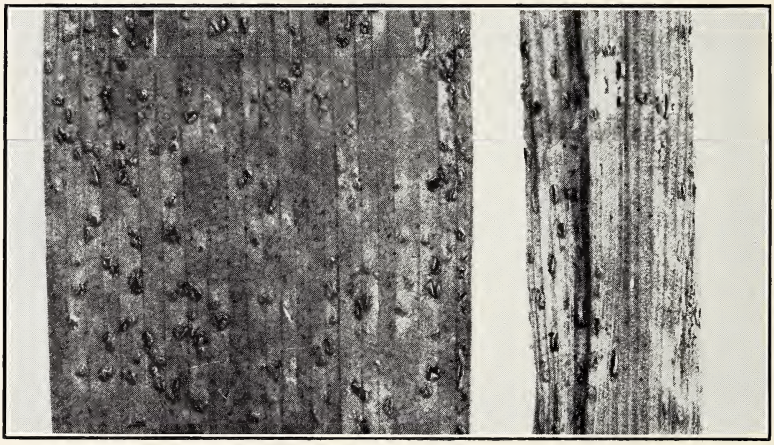

Fig. 4—Rust of Iris. Portion of leaves showing uredinia.

Blue Jay, Queen Alexandra, Quaker Lady, Parc de Neuilly, Carthusian, Albert Victor, Purple King, Madame Chereau, Jacquesiana, Flavescens, Aurea, Rhein Nixe, Parisiana, Lohengrin, Celeste, Florentina alba, Violacea grandiflora, Caprice, Monsignor, Fairy, Pallida dalmatica, Ballerine, Queen Caterina, and Georgia were repeatedly dusted with the spores of the rust without any sign of infection developing.

The lack of infection on such species as *I. fulva*, *I. ensata*, *I. graminea*, *I. pseudacorus*, *I. tectorum* and the Germanica types which have been listed as hosts indicate that either there are strains within these species of different susceptibility or races exist in the rust differing in ability to infect these species. Investigations now in progress are showing that both suppositions are true.

Apparently in the eastern part of the United States teliospores very seldom are formed. The rust probably survives the winter in the uredinial stage on the living leaves of infected plants. Destruction of leaves as soon as uredinia appear in the spring should greatly reduce this rust. Judging from the results obtained with other rusts, dusting with sulphur should control this disease.

TULIP DISEASES.

Botrytis Blight or Fire Disease. This disease of tulips is caused by *Botrytis Tulipae*. This is probably the most important disease of tulips. It is often very destructive in the tulip-growing areas of Europe and has been reported as severe in various parts of the United States. The springs of both 1927 and 1928 at Lafayette were wet and very favorable for the development of this disease. It spread rapidly and several varieties, especially those in partially shaded places, were very severely affected.

The disease usually is first indicated by yellowish to reddish contorted leaves in early spring (fig. 5). Under moist conditions these soon become covered with the grayish mass of conidiophores and spores (fig. 8). Infection rapidly spreads by means of these spores to neighboring plants. Upon these infection first is evident as small water-soaked spots (fig. 6) which increase in size, becoming yellowish or reddish, coalescing and finally involving most or all of the leaf. The flower buds may be infected before they emerge. In such cases they are blasted (fig. 6) and soon become covered with a mass of conidiophores and spores (fig. 7). Sometimes infection develops rapidly when the plant first starts to develop in the spring and oftentimes the plants are killed before they emerge from the ground (fig. 9). When infection takes place, after the flower stalks have reached their full development, the stalks and buds may show a number of brownish spots (fig. 8). The buds are often contorted, either not opening or producing imperfect flowers. Otherwise perfect flowers may be disfigured by numerous brown spots on the petals.

When infection is severe the parts affected are eventually killed and, if under moist conditions, abundant, small, black sclerotia are formed on the infected parts (figs. 9 and 10). These sclerotia serve to carry

the fungus over winter and start the disease the next spring. The dead leaves and stems are oftentimes covered with these sclerotia (fig. 10), and if they are allowed to decay in the soil the sclerotia remain to start infection the following spring. Sclerotia often develop at the

Fig. 5—Botrytis Blight of Tulips. Showing contortion of the leaves characteristic of this disease.

Fig. 6—Botrytis Blight of Tulips. Showing blasted flower buds and secondary infections on upper leaf. The lower leaf has been killed by the fungus.

Fig. 7—Botrytis Blight of Tulips. Showing sporulation of the fungus on early infected flower buds.

Fig. 8—Botrytis Blight of Tulips. Showing effect of late infection on flower buds.

base of the old flower stalks (fig. 9), on the outer brown scales and in lesions on the white scales beneath (fig. 11). These are transported with the bulb and start infection in the spring. In the fall of 1928 sclerotia were found on a number of bulbs which had been received

Fig. 9—Botrytis Blight of Tulips. Showing killing of stems and the production of sclerotia.

Fig. 10—Botrytis Blight of Tulips. Showing the development of sclerotia on debris from diseased tulips.

from Holland (fig. 11). These bulbs were otherwise in good condition, and if they had not been examined specially the sclerotia would have been overlooked. In this way the disease is introduced into gardens which have been free from it.

This disease is difficult to control since the sclerotia carry it over adverse conditions and the abundant production and dissemination of

Fig. 11—Botrytis of Tulip. Showing sclerotia on outer brown scale (left, near top) and lesion on inner white bulb scale (right) on bulbs received from Holland. The disease is introduced into plantings in this way.

conidia in the spring rapidly spread the disease. Care should be taken to plant bulbs free from the disease. Bulbs should not be planted in soil containing debris from diseased plants. As soon as the first signs of disease appear in the spring all diseased parts should be removed and destroyed before spores are produced in order to prevent the disease from spreading.[5]

[5] Hopkins, E. F. The Botrytis Blight of Tulips. Mem. Cornell Uni. Agr. Exp. Sta. 45:311-361. 1921. Review of the literature given.

PRESERVATION OF MONOTROPA AND SIMILAR PLANTS WITHOUT DISCOLORATION.

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We have been asked on several occasions whether plants like Monotropa, which blacken on drying, could possibly be kept with their natural color when preserved in various solutions.

In attacking the problem we surmised that the black color, which did not resemble that which developed on decay or decomposition, was really some plant dye which developed when the plant dried, and if so, the pigment giving the plant its characteristic white color was present as a leuco form of coloring matter which, when left in the presence of air or other substances containing oxygen, was oxidized to become black. With this assumption plants were placed in preservative solutions to which a reducing agent had been added. Sulphur dioxide from sodium acid sulphite has often been used in bleaching colors and dyes, and it was thought that possibly it would reduce the color here too. Our first guess was correct and it was found necessary only to keep the plant permanently in a free sulphur dioxide solution of a preserving fluid. It seemed necessary that the acid sulphite be used only in a medium that does not react to destroy the sulphur dioxide. As long as this latter is present in excess the plant may be kept in alcohol or even in xylol.

The first method and the one which gave the best results was as follows: specimens of the plant were placed in test tubes and the tubes filled with alcohol until the plants were submerged. About one-half a gram of sodium sulphite was added and finally about one-half cubic centimeter of concentrated hydrochloric acid. The tube was then lightly stoppered and shaken. Although the amounts of sodium sulphite and acid were varied slightly, the quantities mentioned above gave the best results. After a period of about two months no discoloration could be noticed. In using alcohol as the primary preservative it was found that there was an excess of sodium sulphite present which formed a cloudy precipitate whenever the tube was agitated or inverted. To obviate this, the tube was left so that the precipitate settled and the liquid was then filtered off. In this way a saturated alcoholic solution of sulphur dioxide was obtained. Finally the specimen was sealed in the tube after replacing the alcohol with xylol, and a little alcohol having sulphur dioxide present, if greater transparency was desired.

Several other methods were tried and gave varying results. Sulphur dioxide in camphor solution was also added to the alcohol or xylol in which the specimens were to be kept. In some cases the specimens darkened after being in the solution but a short time, while others

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

which had been slightly discolored were whitened after being placed in the solution. The amount of camphor solution used ranged from two to twenty drops. Due to the fact that camphor dissolves over three hundred times its weight of sulphur dioxide gas, it is necessary to take but a small amount to obtain the required quantity of the reducing agent. Camphor-sulphur dioxide mixture is not as good as the first solution, inasmuch as the camphor in time removes the gas apparently, by reacting with it.

Attempts were also made to bleach some of the discolored specimens. This was done when none other than discolored specimens were obtainable. Chlorine water and Javelle water were used with interesting results. In these experiments the plants were placed in a solution of alcohol and the chlorine solution added in varying degrees. When more than one cubic centimeter of chlorine water was added it was found that the plant lost its black color, turned yellow, and finally became macerated. More dilute solutions bleached the plants to various degrees. Javelle water seemed to have little effect except in cases where the plant was discolored but a very little. This was undoubtedly due to the fact that no acid was added to the solution to force the evolution of chlorine gas. In some cases specimens bleached by chlorine were sealed in preservatives containing sulphur dioxide. They have retained their whiteness for several months. The chlorine, of course, bleaches the dye found in colored plants, and there is no purpose in using it unless only old darkened plants are at hand. With clean, white specimens available the first method suffices to attain the results desired. Although no work was done with fungi, it is reasonable to believe that the methods described might prove quite satisfactory.

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PERIDIA OF CRUCIBULUM VULGARE.

LEWIS B. LOCKWOOD, Indiana University.

This fungus was first studied by Tulasne, and after the studies of Sachs, published in 1855, no important work was done with reference to it until 1920, when Leva Walker[1] in Nebraska showed that the peridia of *Crucibulum vulgare* grow from mycelial hyphae, from a dense mat of surface hyphae, or not infrequently from the interior of a peridium from which the sporodioles have disappeared.

Early in May, 1928, there was an extremely vigorous growth of peridia from mycelial hyphae about one hundred yards west of Kirkwood Hall, Indiana University. The formation of new peridia within old ones was not observed until the following month, then only in one case. This phenomenon did not occur again until the next August. At that time they were quite common. In September and October it was found in 51 per cent of the emptied peridia collected. Specimens were gathered without reference to this. The growth of young peridia arising from a subicle was not noticed until October 18, 1928. The color of these peridia was that of raw sienna and the color of the subicle was mustard yellow. The mycelium collected at the same place and time was hyaline.

Sections were made to study the development of this plant and to determine the connection between the peridia which grow inside the emptied ones and the mycelium (fig. 1). The sections showed the things which Walker had observed in the development. There was a process of gelatinization, which begins just above the base and beneath the yellow covering and forms a covered dome-shaped crown when the peridium is only about one millimeter high. Before this crown is completely formed the sporodioles begin to differentiate. They first appear as spots of slightly denser hyphae which take the analine safranin stain better than does the ground tissues. After the gelatinization of the dome is complete the ground tissue begins to gelatinize, leaving the sporodioles as round masses attached by their ventral surfaces to remaining masses of ground tissue. The sporodioles become lenticular in shape and the ground tissue to which they are attached forms the funiculus, a wavy mass of hyphae connecting the sporodiole with the inner wall of the peridium, and also a sheath around the funiculus which promptly gelatinizes.

The region of growth was shown by Walker to be at the top. The top surface is flattened when the peridium is about three millimeters high and about the same in diameter at the top. When it is this size the

[1] Walker, Leva B. Development of Cyathus Fascicularis, Cyathus Striatus, and Crucibulum Vulgare. Bot. Gaz. 70:1-24. 1920. Further bibliography listed here.

yellow epiphragm appears. There is a groove around the epiphragm in which the lateral wall of the peridium and the epiphragm are connected.

As the sporodioles assume their mature shape, a central cavity appears in them into which the basidia project. The basidiospores first appear when the peridium is about four millimeters high, but they are not plentiful until it is time for the epiphragm to disappear.

The mycelium which lines the peridial cavity at its base was alive when the peridia were fixed for study. The dead mycelium took the orange G stain, but was only slightly affected by analine safranin and gentian violet, while the living mycelium was stained by these, and only slightly colored with the orange G.

Fig. 1—Longitudinal section through part of an emptied peridium showing the base of the peridial cavity with the young peridium developing from the lining of the old one. x32.

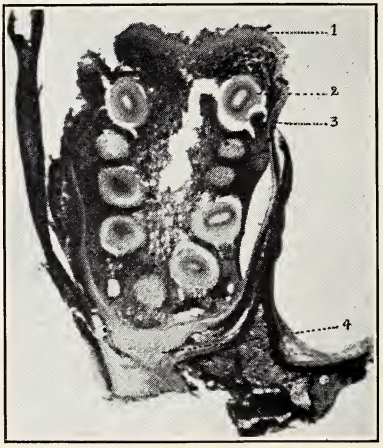

Fig. 2—Longitudinal section through an emptied peridium showing another peridium, nearly mature, which has developed inside it. The inner peridium shows (1) epiphragm, (2) sporodiole, (3) funiculus, and (4), the connection of the second peridium with the lining of the peridial cavity of the first. x20. (Photo-micrograph by Weatherwax).

There was a mass of undifferentiated hyphae which issued from the living lining and extended to the subicle (fig. 2). These hyphae passed into the base of the new peridium which grew out of the lining of the old one. In several cases studied there were two and in one case three peridia growing out of the lining of a single peridial cavity. In these cases the new peridia were confluent, but separated by a layer of yellow-brown very loose hyphae similar to those which cover the young peridia after their earliest stage. These peridia do not always develop equally, one becoming much larger than the other. This causes variation in shape, making some appear to be lanceolate in section rather than wedge-truncate as is normal. They appear to grow out of

the lining of the old peridium at the same place, which may be the bottom of the peridial cavity or may be some point on its side near the bottom.

It is a phenomenon of common occurrence among the mushrooms for one fructification to grow from the sporophore of an older one. *Clytocybe*, *Collybia*, and *Hypholoma*, along with most other genera of caespitose mushrooms, display this characteristic. In these cases the later fructifications grow on the outside of the earlier ones, often before the latter are mature. All the mycelium of the sporophore does not die at the same time, and more sporophores may be produced from part of it. Ordinarily new sporophores are not produced by the mycelium of an older one, but appear only from new hyphae.

Crucibulum vulgare constitutes another exception to the usual order. The mycelium which lines the peridial cavity has living connection with the subiculum and the mycelium in the substratum. This must either contain an excess of food, more than is needed for the maturation of the first peridium, or the absorption of food may continue after the first fruit bodies have been produced. Growth is natural when an excess of food is present, unless other factors intervene, so new peridia are formed from the old peridial mycelium. These correspond to the mushroom sporophores which develop on the sporophore of an older one. In either case the fructification grows from the mycelium of an older sporophore. Usually the young sporophores appear on the outside of the stipe of the mushroom, but in *Crucibulum vulgare* these appear inside the old peridium. The dead wall of the emptied peridium probably protects the mycelium at the bottom of the peridial cavity, and the new peridium, as the subiculum could not protect it.

The author is indebted to Profs. David M. Mottier and J. M. Van Hook for criticism of this paper.

ALGAE OF INDIANA—A CLASSIFIED CHECK LIST OF THOSE PUBLISHED BETWEEN 1875 AND 1928.

C. MERVIN PALMER, Butler University.

Few papers have been published giving the names of the algae of Indiana. Out of a total of 27 papers which mention the algae, only 14 list more than ten. In spite of this, 787 specimens have been identified, representing 589 genera and species. Omitting the genus synonyms there are 132 genera reported.

Out of the 96 counties in the state, algae have been reported in print from only 17. Only nine of the 17 are represented by more than ten algae. These nine counties are Monroe, Marshall, Marion, Lake, Tippecanoe, Kosciusko, Wayne, Lawrence, and Montgomery. Four counties are represented by two or more Blue Green Algae; six counties report more than one desmid; five counties report more than one diatom; ten counties report more than one of the other algae. The genera best represented in number of species are Cosmarium with 31 species, Staurastrum with 29 species, Navicula with 19 species, and Spirogyra with 22 species.

Genera and species reported for Indiana are listed alphabetically by genus under the four groups: Cyanophyceae, Desmids, Diatoms, and All Other Algae. The genus or species authority, if it is found in the original article, is given for each. The county or counties in which each kind of alga is reported, together with the date when the names were published are given. Genus names which are considered as synonyms by West and Fritsch in "British Freshwater Algae" (1927) are printed in italics. Many corrections in spelling have been made. The author has identified 20 species of algae of Marion County during 1928. Since all of the 20 are new for the county and five are new for the state, they are included in the following list.

GROUP 1. BLUE GREEN ALGAE (CYANOPHYCEAE):

Anabaena. Tippecanoe Co. 1895; Monroe Co. 1908. flos-aquae, Brebisson. Marshall Co. 1920. inaequalis. Monroe Co. 1909. *A. saccata,* (Wolle). Marshall Co. 1920. *A. stagnalis,* ——— or Küetzing, Marshall Co. 1920; Monroe Co. 1926. *A. variabilis.* Monroe Co. 1926.

Aphanizomenon. *A. flos-aquae,* (Linnaeus). Marshall Co. 1920.

Aphanothece. Kosciusko Co. 1901. *A. stagnina* (Sprengel). Marshall Co. 1920.

Arthrospira. *A. jenneri,* (Kuetzing) Stizenberger. Monroe Co. 1908.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

Calothrix. *C. fusca,* B. & F. Marshall Co. 1920. *C. gracilis.* Monroe Co. 1909. *C. gypsophila.* Monroe Co. 1926. *C. juliana,* (Meneghini) Bornet. Monroe Co. 1908. *C. orsiniana.* Monroe Co. 1926. *C. parietina,* (Naegeli) Thuret. Monroe Co. 1908, Marion Co. 1928.

Chamaesiphon. *C. confervicola,* A. Br. Tippecanoe Co. 1896.

Chroococcus. *C. coherens.* Monroe Co. 1909. *C. turgidus,* ——— or (Kuetz.) Monroe Co. 1909 and 1926, Marshall Co. 1920.

Clathrocystis. (Microcystis). Kosciusko Co. 1901 and 1902.

Coeolosphaerium. Kosciusko Co. 1902. *C. kuetzingianum,* Naeg. Marshall Co. 1920.

Cylindrocapsa. *C. geminella.* Monroe Co. 1909.

Cylindrospermum. *C. macrospermum.* Monroe Co. 1909.

Gloeocapsa. *G. aeruginosa.* Monroe Co. 1909. *G. coracina.* Monroe Co. 1909. *G. magma,* ——— or Kuetz. or (Breb.). Marshall Co. 1920; Monroe Co. 1926. *G. polydermatica,* ——— or Kuetz. Monroe Co. 1909; Marshall Co. 1920. *G. rupestris,* Monroe Co. 1909. *G. sanguina.* Monroe Co. 1909.

Gloeotrichia. *G. natans.* Monroe Co. 1909. *G. pisum.* Monroe Co. 1909.

Gomphosphaeria. *G. aponina,* Keutz. Marshall Co. 1920.

Hapalosiphon. *H. braunii.* Monroe Co. 1926. *H. tenuissimus.* Monroe Co. 1909 and 1926.

Lyngbya. *L. aestuarii,* Liebman. Marshall Co. 1920; Kosciusko Co. 1920. *L. juliana,* Menegh. Monroe Co. 1908. *L. ochracea,* (Roth.) Thur. Monroe Co. 1908.

Merismopedia. *M. convoluta,* ——— or Breb. Monroe Co. 1908 and 1909. *M. glauca,* ——— or (Ehren.). Monroe Co. 1909; Marshall Co. 1920; Marion Co. 1928.

Microcystis (see also Clathrocystis). *M. aeruginosa,* Kuetz. Marshall Co. 1920; Kosciusko Co. 1920; Marion Co. 1928.

Nodularia. *N. spumigena,* Mertens. Knox Co. 1913.

Nostoc. Marshall Co. 1900. *N. coeruleum.* Monroe Co. 1926. *N. commune,* ——— or Vauch. Monroe Co. 1908 and 1909. *N. minutissimum,* Kg. Lawrence Co. 1909. *N. muscorum.* Monroe Co. 1926. *N. pruniforme.* Monroe Co. 1909. *N. rupestere.* Monroe Co. 1926. *N. sphaericum.* Monroe Co. 1909. *N. verrucosum,* ——— or Vaucher. Monroe Co. 1908 and 1909; Marshall Co. 1920.

Oscillaria (Oscillatoria). Tippecanoe Co. 1895; Ripley Co. 1896; Marshall Co. 1900; Kosciusko Co. 1901 and 1902. *O. antliaria.* Monroe Co. 1909. *O. broevis.* Monroe Co. 1909. *O. chalybea.* Monroe Co. 1909. *O. cruenta.* Monroe Co. 1909. *O. elegans.* Monroe Co. 1926. *O. froelichii.* Monroe Co. 1909. *O. imperator.* Monroe Co. 1926. *O. limosa.* Monroe Co. 1909. *O. major.* Monroe Co. 1926. *O. natans.* Monroe Co. 1909 and 1926. *O. nigra.* Monroe Co. 1926. *O. percursa.* Monroe Co. 1909. *O princeps.* Monroe Co. 1909. *O. subfusca.* Monroe Co. 1909. *O. tenuis.* Monroe Co. 1909.

Oscillatoria (see also Oscillaria). Wayne Co. 1876; Lawrence Co. 1909; Morgan Co. 1913; Kosciusko Co. 1922. *O. limosa,* (Roth) Ag. Monroe Co. 1908; Marion Co. 1928. *O. major,* Vaucher. Marshall Co. 1920. *O. princeps,* Vauch. Monroe Co. 1908; Marion Co. 1928. *O. tenuis,* Ag. Monroe Co. 1908; Marshall Co. 1920; Marion Co. 1928.

Phormidium. *P. incrustatum,* (Naegeli) Gomont. Var. cataractorum. Monroe Co. 1908. *P. tenue,* (Meneghini) Gomont. Monroe Co. 1908.

Rivularia. Kosciusko Co. 1895 and 1901; Marshall Co. 1900. *R. dura,* ——— or Roth. Monroe Co. 1909; Marshall Co. 1920. *R. echinulata,* (Smith). Monroe Co. 1909; Marshall Co. 1920. *R. haematiles, Agardh.* Marshall Co. 1920. *R. natans,* (Hedw.). Marshall Co. 1920.

Scytonema. *S. calotrichoides.* Monroe Co. 1926. *S. cortex.* Monroe Co. 1926. *S. gracile.* Monroe Co. 1926. *S. myochrous.* Monroe Co. 1909. *S. natans.* Monroe Co. 1909. *S. tolypothrichoides.* Monroe Co. 1909. *S. turfosum.* Monroe Co. 1926.

Sirosiphon (Stigonema). *S. compactus.* Monroe Co. 1926. *S. pluvinatus.* Monroe Co. 1909.

Spirulina. *S. duplex.* Monroe Co. 1909. *S. jenneri,* Kuetzing. Monroe Co. 1909; Marshall Co. 1920.

Stigonema. (See Sirosiphon).

Tolypothrix. *T. distorta.* Monroe Co. 1909. *T. flaccida,* ——— or Kg. Lake Co. 1891; Monroe Co. 1926. *T. lanata,* (Desvaux) Wartmann. Lake Co. 1910. *T. pulchra.* Monroe Co. 1926. *T. rupestris.* Monroe Co. 1926. *T. tenuis,* ——— or Kuetzing. Monroe Co. 1909; Marshall Co. 1920.

GROUP 2. DESMIDS:

Arthrodesmus. *A. convergens.* Monroe Co. 1909. *A. incus,* ——— or Hass. Lake Co. 1891; Monroe Co. 1926. *A. octocornis.* Monroe Co. 1926.

Calocylindrus (Cosmarium) *C. curtus.* Monroe Co. 1926. *C. thwaitesii,* Ralfs. Montgomery Co. 1898.

Closterium. Wayne Co. 1876; Lake Co. 1891. *C. acerosum,* ——— or (Schrank) Ehrenb. Monroe Co. 1908 and 1909. *C. acutum.* Monroe Co. 1909. *C. attenuatum.* Monroe Co. 1909. *C. brebissonii, Delp.* Lake Co. 1891. *C. cucumis,* ——— or Ehrenb. Monroe Co. 1908 and 1909. *C. decussatum.* Monroe Co. 1926. *C. dianae,* ——— or Ehrenberg. Lake Co. 1891; Monroe Co. 1908, 1910 and 1926; Marshall Co. 1920. *C. ehrenbergii,* ——— or Menegh. Monroe Co. 1908 and 1909. *C. gracile,* Breb. Lake Co. 1891. *C. lanceolatum,* Kg. Montgomery Co. 1898; Lawrence Co. 1909. *C. leibleinii.* Monroe Co. 1909. *C. leibleinii,* Kg., var. curtum, West. Montgomery Co. 1898. *C. moniliferum,* ——— or Ehrb. Montgomery Co. 1898; Monroe Co. 1926. *C. nasutum.* Monroe Co. 1926. *C. parvulum.* Monroe Co. 1926. *C. rostratum,* Ehrb. Lake Co. 1891. *C. strigosum,* Breb. Mon-

roe Co. 1908. *C. subcostatum,* Nord. Lawrence Co. 1909. *C. wenus,* Kg. Lake Co. 1891.

Cosmarium (see also Calocylindrus). Wayne Co. 1876; Lawrence Co. 1909. *C. benustum.* Monroe Co. 1909. *C. biretum.* Monroe Co. 1926. *C. botrytis,* ——— or Menegh. Monroe Co. 1908, 1910 and 1926. *C. coelatum.* Monroe Co. 1926. *C. contractum,* Kirch. Lake Co. 1891. *C. cordanum,* Berb. Montgomery Co. 1898. *C. cucumis.* Monroe Co. 1909. *C. dentatum,* Wolle. Lake Co. 1891. *C. globosum,* ——— or Bulnh. Lake Co. 1891; Monroe Co. 1909. *C. granatum,* Berb. Lake Co. 1891; Montgomery Co. 1898; Marshall Co. 1920. *C. holmiense,* var. integrum, Lund. Montgomery Co. 1898. *C. intermedium,* Deponte. Marshall Co. 1920. *C. laeve, Rabenh.* Monroe Co. 1908. *C. latum,* Brebisson. Lake Co. 1891; Marshall Co. 1920. *C. meneghinii,* ——— or Breb. Lake Co. 1891; Monroe Co. 1926. *C. moniliforme,* ——— or Ralfs. Lake Co. 1891; Monroe Co. 1926. *C. naegelianum,* Breb. Montgomery Co. 1898. *C. obsoletum.* Monroe Co. 1909. *C. orbiculatum.* Monroe Co. 1909. *C. ornatum,* Ralfs. Lake Co. 1891. *C. phaseolus,* Breb. Monroe Co. 1908. *C. polymazum,* Nord. Lake Co. 1891. *C. polymorphum,* Nord. Montgomery Co. 1898. *C. pseudobroomei,* Wolle. Montgomery Co. 1898. *C. pyramidatum,* ——— or Breb. Monroe Co. 1908 and 1926. *C. quasillus,* Monroe Co. 1909. *C. sexangulare.* Monroe Co. 1909. *C. speciosum,* ——— or Lund. Montgomery Co. 1898; Monroe Co. 1926. *C. subcrenatum,* Hantzsch. Marshall Co. 1920. *C. suborbiculare.* Monroe Co. 1909. *C. tetraophthalmum,* Kuetzing or Breb. Lake Co. 1891; Monroe Co. 1910.

Desmidium. *D. aptogonium.* Breb. Lake Co. 1891. *D. baileyi,* (Ralfs) Wolle. Lake Co. 1891. *D. quadratum,* Nordstedt. Marshall Co. 1920. *D. swartzii,* ——— or Agardh. Lake Co. 1891; Monroe Co. 1909; Marshall Co. 1920.

Docidium. *D. connatum.* Monroe Co. 1909. *D. crenulatum,* ——— or Rabenhorst. Monroe Co. 1909 and 1910. *D. hirsutum,* Bail. Lake Co. 1891. *D. nodosum.* Monroe Co. 1909. *D. trabecula,* ——— or (Ehrenb.) Naeg. Monroe Co. 1908 and 1926. *D. tridentulum.* Monroe Co. 1926. *D. truncatum.* Monroe Co. 1926. *D. verrucosum* (Bailey). Marshall Co. 1920. *D. verticillatum.* Monroe Co. 1926. *D. woodii.* Monroe Co. 1926.

Euastrum. Wayne Co. 1876. *E. ansatum.* Monroe Co. 1909 and 1926. *E. circulare.* Monroe Co. 1926. *E. crassum.* Monroe Co. 1909. *E. cuneatrum.* Monroe Co. 1909. *E. didelta.* Monroe Co. 1909. *E. elagans.* Monroe Co. 1926. *E. multilobatum.* Monroe Co. 1926. *E. pokornyanum.* Monroe Co. 1926. *E. spinulosum,* Ralfs. Lake Co. 1891. *E. verrucosum,* Ralfs. Lake Co. 1891.

Hyalotheca. Monroe Co. 1908. *H. dissiliens,* ——— or Breb. Lake Co. 1891; Monroe Co. 1909. *H. mucosa.* Monroe Co. 1926. *H. undulata.* Monroe Co. 1926.

Mesotaenium. *M. braunii.* Monroe Co. 1909. *M. clepsydra.* Monroe Co. 1926. *M. endlicherianum,* Naeg. Lake Co. 1891. *M. micrococcum.* Monroe Co. 1926.

Micrasterias. Lawrence Co. 1909. *M. crux-melitensis,* Ehrb. Lake Co. 1891. *M. fimbriata.* Monroe Co. 1926. *M. muricata.* Monroe Co. 1926. *M. papillifera.* Monroe Co. 1909. *M. pseudofurcata.* Monroe Co. 1926. *M. radiosa.* Monroe Co. 1909. *M. truncata.* Monroe co. 1909. *M. truncata,* var. semiradiata, Naegeli. Lake Co. 1891; Marshall Co. 1920.

Penium. *P. berbissoni,* (Mengh.) Ralfs. Montgomery Co. 1898. *P. closteriodes.* Monroe Co. 1926. *P. interruptim,* Breb. Monroe Co. 1908. *P. margaritaceum,* Berb. Montgomery Co. 1898. *P. navicula.* Monroe Co. 1926. *P. spirostriolatum.* Monroe Co. 1926.

Sphaerozosma. *S. excavatum.* Monroe Co. 1926. *S. filiforme.* Monroe Co. 1926. *S. serratum,* Bailey. Lake Co. 1891.

Spirotaenia. *S. bryophila.* Monroe Co. 1926. *S. condensata.* Monroe Co. 1909. *S. obscura.* Monroe Co. 1926.

Staurastrum. Wayne Co. 1876; Lake Co. 1891; Monroe Co. 1908. *S. alternans.* Monroe C. 1909. *S. arachne.* Monroe Co. 1909. *S. aristiferum.* Monroe Co. 1926. *S. artiscon.* Monroe Co. 1909. *S. asperum,* (Ralfs.). Marion Co. 1882. *S. avicula,* ——— or Breb. Lake Co. 1891; Monroe Co. 1926. *S. botrophilum,* Wolle. Montgomery Co. 1898. *S. brebissonii,* Archer. Marshall Co. 1920. *S. brevispina,* Breb. Lake Co. 1891. *S. crenulatum.* Monroe Co. 1926. *S. crytocerum.* Monroe Co. 1909. *S. dejectum,* ——— or Breb. Monroe Co. 1909; Lake Co. 1891. *S. dilatum,* Ehrb. Lake Co. 1891. *S. echinatum,* Breb. Lake Co. 1891. *S. erasum,* Breb., var. espinulosa, Lind. Lake Co. 1891. *S. eustephanum,* Ralfs., var. b. Lake Co. 1891. *S. furcigerum,* Breb. Lake Co. 1891. *S. gracile,* ——— or Ralfs. Lake Co. 1891; Monroe Co. 1909. *S. hirsutum.* Monroe Co. 1909. *S. incisum,* ——— or Wolle. Lake Co. 1891; Monroe Co. 1909. *S. luteolum.* Monroe Co. 1909. *S. margarataceum,* Ehrb. Lake Co. 1891. *S. muticum,* ——— or Breb. Lake Co. 1891; Monroe Co. 1909; Montgomery Co. 1909. *S. orbiculare,* Ralfs. Lake Co. 1891. *S. pentacladum.* Monroe Co. 1926. *S. punctulatum.* Monroe Co. 1926. *S. spongiosum.* Monroe Co. 1909. *S. tricorne,* Breb. Lake Co. 1891. *S. vestitum.* Monroe Co. 1909.

Tetmemorus. *T. brebisonii.* Monroe Co. 1909. *T. giganteus.* Monroe Co. 1926.

Xanthidium. *X. antelopaeum,* Kg. var. polymazum, Nord. Lake Co. 1891. *X. aramatum.* Monroe Co. 1909. *X. fasciculatum.* Monroe Co. 1926.

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GROUP 3. DIATOMS:

Achnanthes (see also Achnanthidium). *A. hungarica.* Monroe Co. 1909.

Achnanthidium (Achnanthes). *A. flexellum,* Smith or (C. M. Vorce). Marion Co. 1882.

Amphora. *A. ovalis,* ——— or Van Heurch & Kuetzing. Marion Co. 1882; Monroe Co. 1909; Marshall Co. 1920.

Asterionella. Tippecanoe Co. 1901; Marshall Co. 1920.

Biddulphia. *B. decipiens,* Van Heurck. Marion Co. 1882.

Cocconeis. Tippecanoe Co. 1901. *C. amygdalma* (forma Major?). Marion Co. 1882. *C. pediculus* E. Marion Co. 1882; Marshall Co. 1920. *C. pinnularia.* Monroe Co. 1926. *C. placentula.* Monroe Co. 1909.

Cocconema (Cymbella). Tippecanoe Co. 1901; Wayne Co. 1876. *C. lanceolatum.* Monroe Co. 1909.

Cyclotella. Tippecanoe Co. 1901. *C. kutzingiana.* Marion Co. 1882. *C. meneghiniana,* (Vorce). Marion Co. 1882.

Cymatopleura. *C. elliptica,* (Breb.), or W. S. Marion Co. 1882. Marshall Co. 1920. *C. solea,* (Breb). or W. S. Marion Co. 1882; Marshall Co. 1920.

Cymbella (See also Cocconema). *C. cymbiformis,* Ehrenb. Marshall Co. 1920. *C. gastroides.* Marion Co. 1882. *C. helvetica* var., Van Heurck. Marion Co. 1882. *C. lanceolata,* ——— or Ehr. Marion Co. 1882; Monroe Co. 1909. *C. maculata,* Kuetz. Marshall Co. 1920. *C. naviculiformis,* Auersw. Marshall Co. 1920. *C. prostrata,* (Berk). Marshall Co. 1920.

Diatoma. Tippecanoe Co. 1901. *D. constrictum,* (Ralfs.). Marion Co. 1882. *D. constrictum* longatum. Marion Co. 1882. *D. elongatum.* Monroe Co. 1909. *D. hiemal,* Van Heurck. Marion Co. 1882. *D. meridion circulare.* Marion Co. 1882. *D. vulgara.* Marion Co. 1882.

Epithemia. *E. argus,* (Ehrenb.) Marshall Co. 1920. *E. gibba,* ——— or Kuetz. Marion Co. 1882; Monroe Co. 1909; Marshall Co. 1920. *E. turgida.* Monroe Co. 1909. *E. zebra,* (Ehrenb.) Marshall Co. 1920.

Eunotia. Wayne Co. 1876; Marion Co. 1882. *E. gracilis.* Monroe Co. 1909. *E. parallela* var. Marion Co. 1882. *E. pectinalis.* Monroe Co. 1909.

Fabulria. Wayne Co. 1876.

Fragilaria. Tippecanoe Co. 1901; Wayne Co. 1876. *F. brevastriata* var. *subacute,* Grun. Marion Co. 1882. *F. capucina.* Monroe Co. 1909. *F. construens.* Marion Co. 1882. *F. lanceolata.* Marion Co. 1882. *F. mutabilis* (W. S.) Marshall Co. 1920. *F. smithiana,* Grun. Marion Co. 1882. *F. ungeriana,* Grun. Van Heurck. Marion Co. 1882. *F. virescus.* Marion Co. 1882.

Gomphonema. Wayne Co. 1876; Marion Co. 1882; Tippecanoe Co. 1901. *G. acuminatum,* Ehr. Marion Co. 1882; Marshall Co. 1920. *G. acuminatum,* Ehr. Marion Co. 1882. *G. aporica.*

Kosciusko Co. 1920. *G. constrictum,* ——— or Ehrenb. Marion Co. 1882; Monroe Co. 1909; Marshall Co. 1920. *G. geminatum.* Monroe Co. 1909. *G. olivaceum,* Ehrenb. Marshall Co. 1920. *G. sphaerophorum* var. *turgidum,* Ehr. Boone Co. 1882. *G. symmetrica* var. *Kutz.* Marion Co. 1882.

Gyrosigna (See also Pleurosigma). *G. attenuatum.* Monroe Co. 1909.

Hantzschia. *H. amphioxys.* Marion Co. 1882. amphioxys minor. Marion Co. 1882.

Hyalodiscus. *H. collettensis.* Marion Co. 1882.

Licmorpha. *L. flabellata.* Monroe Co. 1909.

Melosira. Marion Co. 1882; Tippecanoe Co. 1901. *M. arenaria.* Monroe Co. 1909. *M. crenulata,* (E). Marshall Co. 1920. *M. hyporborea,* Grun. Marion Co. 1882. *M. varians,* ——— or Ag. Marion Co. 1882; Monroe Co. 1909; Marshall Co. 1920.

Meridion. Wayne Co. 1876; Tippecanoe Co. 1901. *M. circulare.* Monroe Co. 1909. *M. constrictum.* Marion Co. 1882.

Navicula (See also Pinnularia). Wayne Co. 1876; Marion Co. 1882; Tippecanoe Co. 1901. *N. alpina.* Monroe Co. 1909. *N. atoneoides.* Marion Co. 1882. *N. borealis,* (Ehr.) Kg. Marion Co. 1882. *N. cryptocephala.* Marion Co. 1882. *N. cuspidata.* Marion Co. 1882. *N. dicephala.* Marion Co. 1882. *N. dicephala,* (C. M. Vorce), var. ambigua Ehr. Marion Co. 1882. *N. gastrum,* E. Marshall Co. 1920. *N. lanceolata,* (Pritchard). Marion Co. 1882. *N. lata.* Marion Co. 1882. *N. lucidula,* Grunow. Marion Co. 1882. *N. major,* Kg. Marion Co. 1882. *N. placentula.* Marion Co. 1882. *N. reinhardtii,* Grun. Marshall Co. 1920. *N. rhyncocephala,* Kuetzing. Marshall Co. 1920. *N. roteana.* Marion Co. 1882. *N. serians.* Monroe Co. 1909. *N. sphaerophora.* Monroe Co. 1909. *N. timodis.* Marion Co. 1882. *N. viridis,* ——— or Vorce. Marion Co. 1882; Monroe Co. 1909.

Nitzschia (See also Trybleonella). Wayne Co. 1876; Tippecanoe Co. 1901; Marion Co. 1882. *N. acicularis.* Monroe Co. 1909. *N. amphioxys.* Marion Co. 1882. *N. bicephila.* Marion Co. 1882. *N. coaretata,* Van Heurck. Marion Co. 1882. *N. constricta.* Monroe Co. 1909. *N. longa.* Marion Co. 1882. *N. sigmoidea.* Monroe Co. 1909. *N. sigmoidea,* var. *obtusa.* Marion Co. 1882.

Pinnularia (Navicula). Wayne Co. 1876; Tippecanoe Co. 1901.

Pleurosigma (Gyrosigma). Wayne Co. 1876; Johnson Co. 1882. *P. spenceri.* Marion Co. 1882.

Podosphenia. Wayne Co. 1876.

Rhoicosphenia. *R. curvata,* (Kuetz). Marshall Co. 1920.

Stauroneis. Wayne Co. 1876; Marion Co. 1882.

Surirella. Wayne Co. 1876; Shelby Co. 1882. *S. biseriata* (C. M. Vorce). Marion Co. 1882. *S. elegans,* Ehr. Van Heurck. Marion Co. 1882. *S. ovata minor.* Marion Co. 1882. *S. ovata radiata.* Marion Co. 1882. *S. ovata var.* Marion Co. 1882.

Synedra. Wayne Co. 1876; Marion Co. 1882; Tippecanoe Co. 1901. *S. acus.* Monroe Co. 1909. *S. acuti.* Marion Co. 1882. *S. amphicephala,* Ktz. Marion Co. 1882. *S. dicephala.* Marion Co. 1882. *S. lanceolata.* Marion Co. 1882. *S. longissima,* W. Sm. Marshall Co. 1920. *S. obtusa,* W. Sm. or Van Heurck. Marion Co. 1882; Marshall Co. 1920. *S. parallelogram.* Marion Co. 1882. *S. pulchella.* Monroe Co. 1909. *S. radians,* W. Sm. Marshall Co. 1920. *S. spathulifiaris,* Grun. Marion Co. 1882. *S. valens.* Monroe Co. 1926.

Tabellaria. Tippecanoe Co. 1901. *T. fenestrata.* Monroe Co. 1909. *T. flocculosa.* Monroe Co. 1909.

Triceratium. Marion Co. 1882.

Trybleonella (Nitzschia). Marion Co. 1882.

GROUP 4. ALL OTHER ALGAE (CHLOROPHYCEAE, RHODOPHYCEAE, PIGMENTED FLAGELLATES AND CHAROPHYTES.)

Ankistrodesmus (See also Rhaphidium). Marshall Co. 1920. *A. falcatus* (Corda) Ralfs. Marion Co. 1928.

Aphanochaete (See Herposteiron).

Batrachospermum. *B. moniliformae.* Monroe Co. 1909.

Botrydium. *B. granulatum,* ——— or Linnaeus. Monroe Co. 1909; Marshall Co. 1920; Marion Co. 1928.

Botryococcus. *B. braunii,* ——— or Kuetzing. Monroe Co. 1909; Marshall Co. 1920.

Bulbochaete. *B. crenulata,* ——— or Pringsh. Monroe Co. 1908 and 1926. *B. intermedia.* Monroe Co. 1909. *B. minor* (A. Braun) Wittrock. Knox Co. 1913. *B. pygmaea* (Pringsheim). Marshall Co. 1920.

Ceratium. *C. hirundinella.* Kosciusko Co. 1895 and 1920. *C. macroceras,* Schrenk. Marshall Co. 1920. *C. tripos.* Kosciusko Co. 1920.

Chaetophora. Tippecanoe Co. 1901; Kosciusko Co. 1901; Marshall Co. 1900. *C. elegans.* Monroe Co. 1909. *C. endiviaefolia* Ag. Monroe Co. 1908. *C. incrassata* (Hudson). Marshall Co. 1920. *C. pisiformis,* ——— or (Roth) Ag. Monroe Co. 1908, 1909, and 1910; Marshall Co. 1920. *C. tuberulosa.* Monroe Co. 1909.

Chara. Lake Co. 1891; Tippecanoe Co. 1895; Marshall Co. 1900; Kosciusko Co. 1901 and 1922. *C. contraria,* A. Braun. Marshall Co. 1920. *C. foliolosa,* Muhlenberg & Willdenow, Marshall Co. 1920. *C. fragilis,* Desv. Marshall Co. 1920. *C. gymnopitys,* A. Braun. Marshall Co. 1920. *C. polyphylla.* Gibson Co. 1875. *C. subverrucosa,* A. Braun. Marshall Co. 1920. *C. vulgaris,* L. Marshall Co. 1920.

Chlamydomonas. *C. pluviale.* Monroe Co. 1909. *C. reticulata,* Gorosch. Marshall Co. 1920. *C. tingens.* Monroe Co. 1909.

Chlorella. Marshall Co. 1920.

Chroolepus (Trentepohlia). *C. aureus.* Monroe Co. 1926.

Chladophora. Marshall Co. 1900; Kosciusko Co. 1901; Lawrence Co. 1909. *C. crispata.* Monroe Co. 1909. *C. flotowiana.* Marshall

Co. 1920. *C. fluitans.* Monroe Co. 1926. *C. fracata.* Monroe Co. 1909. *C. glomerata,* ——— or (Linnaeus) or Kg. Monroe Co. 1908 and 1909; Morgan Co. 1913; Marshall Co. 1920. *C. glomerata,* var. *genuina,* Kirch. Tippecanoe Co. 1896.

Coelastrum. *C. combricum.* Monroe Co. 1909. *C. microporum,* ——— or Naeg. Lake Co. 1891; Monroe Co. 1908 and 1909; Marshall Co. 1920. *C. sphaericum,* Naegeli. Marshall Co. 1920.

Coleochaete. *C. irregularis.* Monroe Co. 1909. *C. scutata,* ——— or Brebisson. Monroe Co. 1908 and 1909; Marshall Co. 1920; Lake Co. 1928. *C. soluta.* Monroe Co. 1909.

Conferva (Tribonema). *C. affinis.* Monroe Co. 1909. *C. floccosa.* Monroe Co. 1909. *C. fugacissima.* Monroe Co. 1909. *C. punctalis.* Monroe Co. 1926. *C. vulgaris.* Monroe Co. 1909.

Crucigenia. *C. tetrapedia,* (Kirchner). Marshall Co. 1920.

Dactylococcus. *D. bicaudatus.* Monroe Co. 1909.

Dictyosphaerium. *D. ehrenbergianum,* Naegeli. Marshall Co. 1920. *D. reniforme,* ——— or Buluh. Monroe Co. 1909; Lake Co. 1891.

Dimorphococcus. *D. cordatus,* Wolle. Lake Co. 1891.

Dinobryon. Tippecanoe Co. 1895 and 1901; Marshall Co. 1920.

Draparnaldia. *D. glomerata,* ——— or (Vaucher). Monroe Co. 1909; Marshall Co. 1920. *D. plumosa,* (Vaucher) Ag. Monroe Co. 1908.

Eremosphaera. *E. viridis,* De Bary. Marshall Co. 1920.

Eudorina. *E. stagnalis.* Monroe Co. 1909.

Euglena. Ripley Co. 1896; Lawrence Co. 1909. *E. acus,* Ehr. (?). Monroe Co. 1910. *E. viridis,* Ehrenberg. Monroe Co. 1910; Marshall Co. 1920.

Gloeocystis. *G. gigas,* (Kütz.) Lagerh. Monroe Co. 1908.

Gonium. *G. pectorale,* Müller. Monroe Co. 1908 and 1909; Marshall Co. 1920. *G. sociale,* (Duj.) Warming. Marion Co. 1928.

Gonatozygon. *G. asperum.* Monroe Co. 1926.

Herposteiron (Aphanochaete). Monroe Co. 1908.

Hydrodictyon. Tippecanoe Co. 1895, 1896; Marshall Co. 1900; Kosciusko Co. 1901. *H. reticulatum,* ——— or Linnaeus or Roth. Lake Co. 1891; Morgan Co. 1910; Owen Co. 1913; Marshall Co. 1920.

Mesocarpus (Mougeotia). Morgan Co. 1913. *M. nummuloides.* Monroe Co. 1909. *M. recurvus.* Monroe Co. 1909. *M. robustus.* Monroe Co. 1909.

Microthamnium. Kosciusko Co. 1901; Marshall Co. 1920.

Mougeotia (See also Mesocarpus and Pleurocarpus). Kosciusko Co. 1901; Marshall Co. 1920. *M. divarecata.* Monroe Co. 1909. *M. genuflexa,* (Dillw.) Ag. Monroe Co. 1908. *M. parvula,* Hass. Monroe Co. 1908. *M. scalaris,* Hass. Monroe Co. 1908.

Myxonema (Stigeoclonium). *M. nanum* (Dillw.) Hazen. Monroe Co. 1908. *M. radians,* (Kuetzing). Marshall Co. 1920. *M. tenue,* (Ag.) Rabenh. Monroe Co. 1908.

Nephrocytium. *N. agardhianum,* Naeg. Monroe Co. 1908.

Nitella. Monroe Co. 1894; Marshall Co. 1900; Kosciusko Co. 1901. *N. batrachosperma,* (Reichenbach). Marshall Co. 1920. *N. monodactyla,* A. Braun. Marshall Co. 1920. *N. mucronata,* A. Braun. Marshall Co. 1920. *N. tenuissima,* (Desv.) Marshall Co. 1920.

Oedogonium. Tippecanoe Co. 1901; Kosciusko Co. 1901; Marshall Co. 1900; Lawrence Co. 1909. *O. crassiusculum,* Wittr. Monroe Co. 1908. *O. crassum.* Monroe Co. 1909. *O. crytoporum,* Wittr. Monroe Co. 1908. *O. boscii,* (Le Clerc). Marshall Co. 1920. *O. fonticula.* Monroe Co. 1909. *O. granda,* Kuetzing. Knox Co. 1913. *O. irregulare.* Monroe Co. 1926. *O. landsburoughii,* (Hass.). Marshall Co. 1920. *O. longatum,* Kuetzing. Marshall Co. 1920. *O. obtruncatum.* Monroe Co. 1909. *O. sexangulare.* Monroe Co. 1909. *O. undulatum,* ——— or Brebisson. Monroe Co. 1910 and 1926.

Ophiocytium. *O. arbuscula,* (A. Braun) Rabenhorst. Knox Co. 1913. *O. bicuspidatum,* (Borge) Lemm. Monroe Co. 1908. *O. cochleare,* A. Br. Lake Co. 1891.

Palmella. Kosciusko Co. 1895.

Pandorina. Tippecanoe Co. 1895. *P. morum,* ——— or (Müll) Bory. Monroe Co. 1908 and 1909; Lawrence Co. 1909.

Pediastrum. Wayne Co. 1876. *P. angulosum.* Monroe Co. 1926. *P. boryanum,* ——— or Turpin or Menegh. Lake Co. 1891; Monroe Co. 1908 and 1909; Lawrence Co. 1909; Marshall Co. 1920; Marion Co. 1928. *P. duplex,* Meyen. Marshall Co. 1920; Marion Co. 1928. *P. ehrenbergii,* Corda. Lake Co. 1891; Marshall Co. 1920. *P. pertusum.* Lake Co. 1891; Monroe Co. 1909. *P. simplex.* Monroe Co. 1926. *P. strumii.* Monroe Co. 1926. *P. tetras.* Monroe Co. 1909.

Peridinium. Tippecanoe Co. 1895 and 1901. *P. tabulatum,* Ehrenberg. Monroe Co. 1910; Marshall Co. 1920.

Phacus. *P. pleuronectes,* Müller. Monroe Co. 1910. *P. pyrum,* Ehrenberg. Monroe Co. 1910.

Pleodorina. *P. californica,* Shaw. Tippecanoe Co. 1895; Monroe Co. 1894. *P. illinoisensis,* Kofoid. Marion Co. 1928.

Pleurocarpus (Mougeotia). *P. mirabilis.* Monroe Co. 1909.

Pleurococcus (See also Protococcus). Lawrence Co. 1909. *P. viridis.* Monroe Co. 1909. *P. vulgaris,* Menegh. Monroe Co. 1908; Marion Co. 1928.

Polyedrium (Tetraedron). *P. enorme,* Rab. Lake Co. 1891. *P. minimum.* Monroe Co. 1926. *P. minutum,* A. Br. Lake Co. 1891. *P. muticum,* A. Br. Lake Co. 1891. *P. trigonum,* Naeg. var. bifurcatum, Wille. Lake Co. 1891. *P. trigonum,* Naeg. var. tetragonum, Rab. Lake Co. 1891. *P. trigonum,* Naeg. var. typicum, Kirch. Lake Co. 1891.

Porphyridium. *P. cruentum.* Monroe Co. 1926.

Prasiola. *P. parietina,* (Vaucher). Marshall Co. 1920.

Protococcus (Pleurococcus). Tippecanoe Co. 1895 and 1901; Marshall Co. 1900. *P. viridis,* Ag. var. gigas. Lake Co. 1891.

Rhaphidium (Ankistrodesmus). Tippecanoe Co. 1901. *R. polymorphum.* Monroe Co. 1909. *R. convolutum.* Monroe Co. 1909.

Rhizoclonium. *R. fontinali.* Monroe Co. 1926.

Scenedesmus. Tippecanoe Co. 1895 and 1901; Lawrence Co. 1909. *S. abundans,* Kirchner. Marshall Co. 1920. *S. acutus.* Monroe Co. 1909. *S. caudatus,* ——— or Corda. Lake Co. 1891; Monroe Co. 1908 and 1909. *S. caudatus,* Corda, var. *abundans,* Kirch. Lake Co. 1891. *S. dimorphus,* ——— or Kg. Lake Co. 1891; Monroe Co. 1909; Marion Co. 1928. *S. obliquus* (Turpin). Marshall Co. 1920; Marion Co. 1928. *S. obtusus,* ——— or Meyen. Monroe Co. 1908 and 1909; Lake Co. 1891. *S. quadricauda,* (Turp.) Brebisson. Marion Co. 1928. *S. rotundatus.* Monroe Co. 1926.

Schizomeris. *S. liebleinii,* Kuetzing. Marshall Co. 1920.

Sorastrum. Marshall Co. 1920. *S. spinulosum.* Monroe Co. 1909; Lake Co. 1890.

Sphaerella. *S. pluvialis.* Monroe Co. 1909.

Spaerocystis. *S. schroeteri,* Chod. Lawrence Co. 1909.

Spirogyra. Wayne Co. 1876; Tippecanoe Co. 1895, 1896; Ripley Co. 1896; Marshall Co. 1900; Kosciusko Co. 1901 and 1922; Morgan Co. 1913; Lawrence Co. 1909. *S. adnata.* Monroe Co. 1926. *S. communis.* Monroe Co. 1909. *S. condensata,* (Vaucher). Marshall Co. 1920. *S. crassa,* ——— or Kütz. Monroe Co. 1908 and 1909; Marion Co. 1928. *S. decimina.* Monroe Co. 1909. *S. dubia.* Monroe Co. 1926. *S. elongata.* Monroe Co. 1926. *S. fusco-atra.* Monroe Co. 1909. *S. gracilis.* Monroe Co. 1909. *S. inflata,* ——— or (Vauch.) Rabenh. Monroe Co. 1926 and 1908. *S. jugalis.* Monroe Co. 1909. *S. longata.* Monroe Co. 1909. *S. majuscula,* Kuetzing. Monroe Co. 1910; Marshall Co. 1920. *S. mirable,* Hass. Marshall Co. 1920. *S. neglecta,* (Hass.) Kütz. Monroe Co. 1908. *S. nitida,* ——— or (Dillw.) Link. Monroe Co. 1909 and 1908. *S. quadrata.* Monroe Co. 1926. *S. quinina.* Monroe Co. 1909. *S. rivularis,* ——— or Rabenh. Monroe Co. 1926 and 1908. *S. setiformis.* Monroe Co. 1909. *S. varians* (Hass.) Kütz. Monroe Co. 1908. *S. weberi,* Kütz. Monroe Co. 1908.

Stichococcus. Monroe Co. 1908.

Stigeoclonium (See also Myxonema). Marshall Co. 1900. *S. nanum.* Monroe Co. 1909. *S. thermale.* Monroe Co. 1926.

Tetraedron (See also Polyedrium). *T. minimum,* (A. Braun). Marshall Co. 1920.

Tetraspora. *T. cylindrica.* Monroe Co. 1909. *T. lubrica,* ——— or (Roth) Ag. Monroe Co. 1908 and 1909; Marshall Co. 1920.

Trachelomonas. Tippecanoe Co. 1895. *T. annata,* Ehrenberg. Monroe Co. 1910. *T. hispida,* (Perty) var. cylindrica, Klebs. Marion Co. 1928.

Trentepohlia (See Chroolepus).

Tribonema (See also Conferva). *T. bombycinum,* (Agardh.) Marshall Co. 1920.

Ulothrix. *U. aequalis,* ——— or Kütz. Monroe Co. 1908 and 1926. *U. muralis.* Monroe Co. 1909. *U. subtilis,* ——— or Kutz. Monroe Co. 1908 and 1909. *U. tenuissima,* Kuetzing. Marshall Co. 1920. *U. zonata,* ——— or (Webber & Mohr) Aresch. Marshall Co. 1920; Monroe Co. 1908 and 1926.

Uroglena. Tippecanoe Co. 1896 and 1901.

Vaucheria. Ripley Co. 1896; Marshall Co. 1900 and 1920; Lawrence Co. 1909. *V. aversa.* Monroe Co. 1926. *V. dillwynii.* Monroe Co. 1909. *V. geminata,* ——— or (Vauch.) D. C. Monroe Co. 1909 and 1908; Marion Co. 1928. *V. sericea.* Monroe Co. 1909. *V. sessilis,* ——— or (Vauch.) D. C. Monroe Co. 1908 and 1909; Marion Co. 1928. *V. terristris.* Monroe Co. 1909.

Volvox. Kosciusko Co. 1922. *V. aureus,* Ehrenberg. Marshall Co. 1920; Kosciusko Co. 1920; Lawrence Co. 1909. *V. globator,* ——— or Ehrenberg or Linnaeus. Monroe Co. 1909; Lawrence Co. 1909; Knox Co. 1913.

Zygnema. Ripley Co. 1896; Marshall Co. 1900 and 1920; Lawrence Co. 1909; Morgan Co. 1913; Kosciusko Co. 1922. *Z. anomalum.* Monroe Co. 1909. *Z cruciatum,* ——— or Ag. Monroe Co. 1908 and 1926. *Z. insigne,* ——— or Kütz. Monroe Co. 1909 and 1908. *Z. leiospermum,* ——— or De Bary. Monroe Co. 1908 and 1909. *Z. stellium.* Monroe Co. 1926. *Z. stetlum,* Agardh. Monroe Co. 1910.

Zygogonium. *Z. decussatum.* Monroe Co. 1909. *Z. parvulum.* Monroe Co. 1926. *Z. pectinatum.* Monroe Co. 1926.

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TUFA DEPOSITS AT CLIFTY FALLS STATE PARK.

REXFORD F. DAUBENMIRE, Butler University.

The river bluffs in the vicinity of Clifty Falls State Park are underlaid with limestone of both the Upper and Lower Silurian deposits. The erosion of Clifty Creek and its tributaries displays many sheer cliffs of these limestone formations along the sides of the canyons. The Upper Silurian is very near the surface of the soil and consists of a 35-foot group of deposits. In places eighty to ninety feet of Lower Silurian shows below the latter, but the present article is concerned only with the Upper Silurian and especially the top layer. This layer consists of 24 feet of limestone. Recently the writer's attention was attracted to three deposits of tufa along this layer where it is bared along the sides of Hoffman's Hollow.

Perhaps an explanation of the general nature of tufa would make the meaning of the present article more clear. Tufa is an incrustation of carbonate of lime around a nucleus of organic matter, such as debris of leaves and twigs or growing mosses and liverworts. G. W. Wilson[1] reported a bed of travertine along the west bank of the Wabash River in Tippecanoe County. The term travertine is applied generally to all calcareous deposits on plant matter, and especially to the more extensive beds. Tufa is a more definite name for deposits of a porous and less compact structure formed from springs. Sinter is used occasionally as a synonym for tufa.

Hoffman's Hollow is a side canyon running approximately northeast from the main hollow of Clifty Creek. The upper eastern half of Hoffman's Hollow consists of a shallow ravine with a creek which, at Hoffman's Falls, drops some ninety feet into the "box canyon" half of the hollow.

In the upper and shallower portion of the ravine there appears frequently a small cliff of limestone extending along the banks of the stream. Along one of these small cliffs on the north side there are two deposits of tufa. The third deposit is found along the talus of the box canyon several hundred yards west from the falls.

One of the deposits in the ravine is quite small and consists of an irregular mass of tufa built over loose stone and soil (fig. 1, A). In this instance the seepage is from a limestone shelf very near the level of the flats, from which the water falls about 12 feet. The tufa found in all three deposits is formed by the moss, *Mniobryum albicans* (Wahlenb.) Limpr., which seems to be the most active nucleus for the incrustation.

The other deposit in this shallower half of the Hollow has been molested by the conversion of its seepage into a drinking fountain. The

[1] Proc. Ind. Acad. Sci., 1905: pp. 183-184. 1906.

water now runs from a pipe driven back into the stone, whereas it once seeped from the limestone a few feet above the floor and under a shelf of rock (fig. 1, B). Here it has built around the Mniobryum an irregular oval mass on the slanting surface of the rock. At the bottom of this mass there is a pool from which the seepage overflows down an irregular surface of loose rock and soil forming smaller and scattered mats of tufa for a few feet.

The third deposit is larger than these last two and in all probability is least molested since it is in a rather remote situation. This formation is along the same limestone layer but has a northern exposure. Here water seeps from a fault in the limestone which resulted in a vertical fissure in the cliff several inches wide (fig. 1, C). The tufa has completely clogged the lower four feet of the crevice. This deposit is some three feet in diameter at the bottom and is in the form of a truncated cone. It is fairly well covered by the Mniobryum which is especially luxuriant in growth in and around the pool on the summit

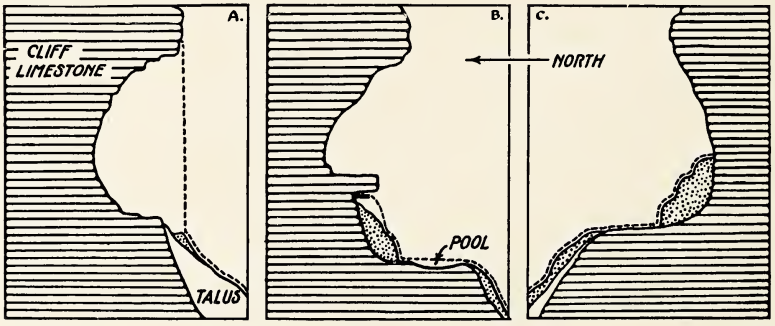

Fig. 1—Diagramatic sections through limestone cliffs at points where tufa is formed.

in which the rivulet pours. The seepage trickles down rather evenly all over the surface and after crossing the narrow path at the base forms an irregular and spread-out secondary mass of tufa followed by several successive smaller masses growing directly below it on the slope. A secondary succession of mosses is growing on the cliff along the edges of the damp tufa. *Amblystegium irriguum* (Wils.) B. & S. grows in a narrow strip around both sides and around the top. On the eastern margin, which is more protected and more moist, *Gymnostomum curvirostre* (Ehrh.) Hedw. interrupts the Amblystegium near the summit of the deposit. On November 4, 1928, large beads of Nostoc were growing on this moist surface in and around the Gymnostomum.

A comparison of all three deposits as to shelter, exposure, flora and source of seepage shows marked resemblances. The immediate surroundings of the two deposits in the upper end of the hollow are not quite so heavily forested as those of the lower deposit, but the former have a southern exposure which probably makes up for this deficiency. All three deposits are in rich mesophytic situations. They are all fairly well protected by the projection of the cliff as can readily be seen from

the diagrams. Mniobryum is in these three instances the active nucleus for the incrustations. The seepage comes from between loose layers of limestone in the first two instances and from a fault in the stone in the last. All are along the same geological layer of limestone.

There are possibly two general reasons for the presence of these beds. First, the presence of calcareous mineral which for some reason was deposited around the moss; and secondly, the protection offered by the projecting cliffs and trees which probably checked erosion. What factor is actually responsible for the precipitation of the mineral from the drain water would be a problem in itself. It is probably due to the photosynthetic action of the Mniobryum in which it absorbs the carbon dioxide from the solution and to evaporation when the water, spread out over greater surface of moss, comes in contact with air currents. That evaporation may be one of the factors causing the precipitation seems clear when it is recalled that stalactites and stalagmites in caves are formed by evaporation and reduced carbon dioxide pressure. Tufa has a comparatively rapid growth requiring high precipitation in a short time. This condition could occur since the seepage spread out over a relatively larger area of moss comes in contact with dryer currents of air.

Subterranean streams and seepage are known to contain an excess amount of carbon dioxide, which is held by the pressure naturally incurred. When limestone is exposed to carbon dioxide it breaks down yielding excess amounts of carbonate of lime to the water before it appears at the surface. On leaving the crevice the consequent reduction of pressure alone could make possible the precipitation. Furthermore, the moss, which is partly submerged, would use up carbon dioxide in its photosynthetic processes and this would still more reduce the amount of carbon dioxide in solution. Seemingly, therefore, the seepage precipitates carbonate of lime because of evaporation and because of a loss of carbon dioxide.

INDIANA FUNGI—XI.

J. M. VAN HOOK, Indiana University.

BASIDIOMYCETES.

UREDINEAE.

Dicaeoma Impatientis (Schw.) Arth. (*Aecidium Impatientis* Schw.). On leaves of *Impatiens pallida* Nutt., woods, Clay County, May 26, 1928. Otho Shaw. I. U. 4917.

Dicaeoma Sambuci (Schw.) Arth. (*Aecidium Sambuci* Schw.). The aecial stage on leaves and petioles of *Sambucus canadensis* L., Clay County, May 26, 1928. Shaw. I. U. 4918.

Melampsora Biglowii Thuem. On *Salix nigra* Marsh., Clay County, August 1, 1927. Shaw. I. U. 4851.

AGARICACEAE.

Favolus canadensis Kl. On dead branch of *Ulmus*, Clay County, May 20, 1928. Shaw. I. U. 4899.

Panus rudis Fr. On decayed wood, Clay County, May 20, 1928. Shaw. I. U. 4905.

Pleurotus ostreatus Jacq. On dead wood, Posey County, May 12, 1928. Shaw. I. U. 4907.

Psilocybe cernua Fr. On humus in old orchard, Clay County, April 29, 1928. Shaw. I. U. 4887.

POLYPORACEAE.

Fomes Everhartii Ell. & Gall. On *Quercus velutina* Lam., Clay County, April 29, 1928. Shaw. I. U. 4888.

Polyporus arcularius (Batsch.) Fr. On old wood of *Fraxinus*, Clay County, May 20, 1928. Shaw. I. U. 4901.

Polyporus hirsutulus Schw. On wood of *Rosaceae*, Monroe County. I. U. 4868.

Polyporus lucidus Leyss. (*Fomes lucidus* (Leyss.) Fr. On deciduous wood, Spencer County, May 10, 1927. Deam. I. U. 4867.

HYDNACEAE.

Hydnum coralloides Scop. Growing in top of large beech tree, Fayette County, October, 1928. Mrs. Charles W. Masters. I. U. 4929. This specimen is of an unusually compact and rounded form.

ASCOMYCETES.

Caryospora putaminum (Schw.) De Not. On old peach pits on ground, Clay County, May 26, 1928. Shaw. I. U. 4914. Also on decorticated wood of *Maclura aurantiaca* Nutt., some thirty yards from the specimens on seeds of peach (I. U. 4915).

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

Both were very abundant. Since the two seem to be identical in description, they are evidently the same and the osage orange is a new host for this most interesting fungus.

Claviceps purpurea (Fr.) Tul. On *Ammophila arenaria* (L.) Link, Michigan City, August, 1928. Weatherwax. I. U. 4927. Common on the sand dunes of Lake Michigan. Also on *Glyceria septentrionalis* Hitchc., Steuben County, August, 1928. Weatherwax. I. U. 4928.

Diatrype albopruinosa (Schw.) Cke. On twigs of deciduous wood, Clay County, May 19, 1928. Shaw. I. U. 4923.

Diatrype corniculata Ehrb. On *Fraxinus*, Clay County, May 5, 1928. Shaw. I. U. 4903.

Diatrype stigma Hoff. On *Quercus velutina*, Clay County, May 5, 1928. Shaw. I. U. 4904.

Dothiorella fraxinicola. On *Fraxinus americana* L., Clay County, May 5, 1928. Shaw. I. U. 4913.

Dothiorella quercina (C. & Ell.) Sacc. On dead twigs of *Quercus*, Clay County, April 29, 1928. Shaw. I. U. 4893.

Eutypella glandulosa (Cke.) E. & E. On twigs of *Ailanthus glandulosa* Desf., Clay County, April 29, 1928. Shaw. I. U. 4892. Corresponds well with the descriptions. We find the asci 25 to 30 by 7 to 10 microns with the p. sp. about one-half the length, and the spores 4 to 5 microns and much curved.

Exoascus deformans (Berk.) Fckl. On peach, Clay County, May 20, 1928. Shaw. I. U. 4906.

Hypoxylon annulatum (Schw.) Mont. On decorticated wood of *Quercus*, Clay County, May 19, 1928. Shaw. I. U. 4922. Also on dead wood of *Quercus alba* L., Monroe County, January 12, 1928. Amidei. I. U. 4866.

Hypoxylon coccineum Bull. On dead branches of *Quercus rubra* L., Hamilton County, September 8, 1909. Pickett. I. U. 4837.

Hypoxylon effusum Nke. On log of *Ulmus*, Clay County, May 5, 1928. Shaw. I. U. 4896.

Hypoxylon marginatum (Schw.) Berk. On old decorticated wood, Clay County, May 19, 1928. Shaw. I. U. 4921.

Hysteriographium Mori (Schw.) Rehm. On dead decorticated *Ulmus*, Monroe County, April 29, 1928. Lockwood. I. U. 4889. On wood of *Quercus*, May 19, 1928. Shaw. I. U. 4912.

Massaria epileuca B. & C. On twigs of *Morus alba* L. var. *pendula* Dipp., Monroe County, May, 1928. I. U. 4897. This species has been reported from New Jersey and Pennsylvania by Ellis and Everhart on *Morus alba* L. (N. A. P. p. 402).

Ophiobolus anguillides (Cke.) Sacc. On dead stems of *Ambrosia trifida* L., May, 1927, Monroe County. The resemblance of the spores to that of a serpent is most striking, especially in fresh specimens. The likeness is particularly shown in the curving and in the longer, enlarged, slightly darker cell at the curved end, with a drop of mucilaginous matter hanging to it. The asci are 85 to 127 by 9 to 12 microns and the spores 110 to 125 by 3 to 4.

Patellia sanguinea (Pers.) Rehm. (*Tapesia sanguinea* Fckl.). On *Sassafras officinale* Nees. Between dry splinters of the wood, some four feet above ground. In woods, Monroe County, April 19, 1928. I. U. 4886. Very typical of description.

Plowrightia morbosa (Schw.) Sacc. On limbs of blue plum, Clay County, May 20, 1928. Shaw. I. U. 4900.

Rosellinia mutans (C. & P.) Sacc. On old wood of *Ulmus*, Posey County, May 12, 1928. Shaw. I. U. 4898.

Sarcoscypha floccosa Schw. On buried dead twigs of *Juglans*, Monroe County. I. U. 4871.

FUNGI IMPERFECTI.

SPHAEROPSIDALES.

Ascochyta graminicola Sacc. On leaves and sheathes of *Triticum vulgare* Vill., Monroe County, July, 1927. I. U. 4853. Spores, 10 to 20 microns in length.

Coniothyrium concentricum (Desm.) Sacc. On leaves of *Yucca filamentosa* L., Clay County, April 29, 1928. Shaw. I. U. 4890. Our spores measure about one micron more in diameter than in recorded descriptions, and are only a few guttulate.

Myxosporium nitidum B. & C. On twigs of *Cornus alternifolia* L. In ravine north of Bloomington, Monroe County, January 14, 1928. Amidei. The yellowish orange color of the twigs is characteristic of the effect of this species.

Phyllosticta Catalpae E. & M. On leaves of *Catalpa speciosa* Warder., Monroe County, October 26, 1926. Eaton. I. U. 4875.

Phyllosticta Juglandis (D. C.) Sacc. On living leaves of *Juglans regia* L., Monroe County (I. U. Campus), October 25, 1927. I. U. 4855. Our pycnidia are about 70 microns in diameter, with distinct pores, abundant oval hyaline spores which average about 3 by 5 microns, and are not guttulate. The description of *P. juglandina* Sacc. very nearly corresponds to that of *P. Juglandis* (D. C.) Sacc., a slight spore difference being noted. These trees, now some 15 years old, were grown from seeds gathered in this country. Hence we might infer that we have here a new species or that these trees have become infected from some heretofore unnoticed fungus present on one of our native species. The recorded description of the fungus is fair only.

Phyllosticta limitata Pk. On leaves of apple (var. Transparent), Monroe County, 1927. I. U. 4836.

Septoria sambucina Pk. On leaves of *Sambucus canadensis* L., east part of campus, October 25, 1928. I. U. 4936. Also on south campus, August 4, 1927. I. U. 4808. Without doubt the species described by Peck (28 Rep. of the St. Mus. N. Y. 1874) from Buffalo, N. Y. We add here a redescription. Spots 1 to 10 mm., sometimes circular, but more often limited by veins making them semi-circular or irregular, pale ashen with a broad, purplish-brown border, beneath a greenish brown. (The older spots are inhabited by various fungi, which, late in the

season, extend the spot, changing its size, color, etc. Among these fungi are a species of *Botrytis* with simple conidiophores, an *Alternaria*, and a *Cladosporium*.) The pycnidia are numerous, amphigenous, but chiefly epiphyllous, often occurring in patches over the spots, 50 to 125 microns in diameter, in surface view appearing darker around the pore due to its protruding. The pore is circular, oval, somewhat irregular or slightly torn in age, very distinct and from 15 to 65 microns in diameter. The spores are very slender, 25 to 50 by 1 to 2 microns, obsoletely septate, variously bent and curved, mostly slightly enlarged at one end, hyaline and very numerous.

Sphaeropsis ulmicola E. & E. On bark of dead twigs of *Ulmus* species (probably *Ulmus americana* L.), Vigo County, May 6, 1928. Shaw. I. U. 4895. The spores average slightly smaller than in published descriptions. The bases of the pycnidia are applanate or truncate as described for *S. Ulmi* Karst.

MELANCONIALES.

Colletotrichum lagenarium (Pass.) Ell. & Hals. On watermelon (*Citrullus vulgaris* Schrad.), Owen County, September, 1925. I. U. 4864.

Gloeosporium Caryae Ell. & Dear. On leaves of *Carya alba* (L.) K. Koch, campus I. U., September, 1928. I. U. 4925. Leaf injury caused by this fungus is very severe each year. The large spots spread over entire leaflets.

Gloeosporium Fagi (Desm.) E. & E. On living leaves of *Fagus ferruginea* Ait., Monroe County, July 7, 1924. I. U. 4126. This fungus was of considerable note in 1924.

Marsonia ochroleuca (B. & C.) Humph. On leaves of *Quercus texana* Buckley (*Q. Schneckii* Britt.), Posey County, September, 1927. Shaw. I. U. 4894. This is apparently a new host for this fungus, previously confined, so far as I am able to learn, to *Castanea dentata* (Marsh) Borkh.

Pestalozzia Guepinia Desm. On leaves of cultivated Rhododendron, Monroe County, January 10, 1928. Amadei. I. U. 4869.

HYPHOMYCETES.

Cercospora Apii Fresen. In market, common on *Apium graveolens* L. I. U. 4878.

Cercospora cercidicola Ell. On leaves of *Cercis canadensis* L., Clark County, August 14, 1923. I. U. 4911.

Cercospora Heucherae Ell. & Mart. On lower leaves (apparently those of last year) of *Heuchera americana* L., Cass County, May 18, 1928. I. U. 4908. Very common in deep ravines. Material very fine. Agrees well indeed. The conidiophores here are mostly epiphyllous. The spores given as 25 to 50 by 3 microns, are here about 25 to 150 by 3, and few to many septate. The spores and conidiophores on the upper surface of the leaf under a good hand lens appear like star-shaped hairs.

Cercospora physalicola Ell. & Barth. On leaves of *Physalis*, Deckard Creek, Monroe County, September 30, 1923. I. U. 3987. The outstanding characteristics of these specimens are the definite spots and the long lash-like spores, tapering above, many being as much as 150 microns long and multi-septate, some folding near the middle on drying. Agrees well except that our spores are often multi-septate rather than 4 to 6-septate as described.

Ovularia obliqua (Cke.) Oud. On leaves of *Rumex crispus* L., Clay County, May 19, 1928. Shaw. I. U. 4916.

Ramularia dubia Riess. On leaves of *Chenopodium album* L., near campus, Monroe County, September 24, 1928. I. U. 4941. Very abundant. The redescription given in Proc. Ind. Acad. Sci., 1925, p. 236, for specimens from Shelby County applies equally well to these specimens.

Ramularia Taraxici Karst. On *Taraxicum officinale* Weber. Campus, October 15, 1927. I. U. 4845. Spots as in description, but up to 1 cm. Spores 1-celled, becoming 1 to 2-septate, cylindrical, sometimes broader at one end or narrowed at middle, often in chains, 15 to 35 by 2 to 4 microns.

SOME NEW SPECIES OF FUNGI.

J. M. VAN HOOK, Indiana University.

CERCOSPORA CYNOGLOSSI *sp. nov.*

Spots numerous, greenish-purple above, mouse colored below, becoming brown above and greenish-brown below when dried, circular or oval, from a few mm. to 2 or 3 cm. in diameter, but average about 1 cm. Conidiophores tufted, 25 to 150 by 2.5 to 4 microns, reddish-brown, tips pale and somewhat wavy due to spore attachment. Spores 6 to 8 on each conidiophore, hyaline, straight, or variously bent or curved, 3 to 10-septate, 40 to 155 by 2.5 to 4 microns (average about 65 to 70 in length).

On living leaves of *Cynoglossum officinale* L., Showers' Farm, Monroe County, Indiana, August 25, 1920. I. U. Myc. Herb. 3815; Deckard Creek, Monroe County, Indiana, September 30, 1923. I. U. Myc. Herb. 3984.

CERCOSPORA ROSAE *sp. nov.*

Spots 1 to 5 mm. (average 2 to 3 mm.), circular, oval, or angular, somewhat limited by veins, amphigenous, above purplish-black, becoming brown in center, with broad purplish-black margin, the purple disappearing with age, circular or irregular, below olive-brown to hair-brown. Conidiophores for the most part epiphyllous, few, in tufts from tuberculate bases as much as 25 microns broad, upright, straight, or sometimes wavy above, 60 to 100 by 4 to 6 microns, for the most part continuous.

Spores 30 to 95 by 5 to 7 microns, bent or sometimes straight, 4 to 7-septate, tapering above, brown (most of these spores are 65 by 6, and 5-septate).

On *Rosa setigera* Michx., campus I. U. (Old Forest Place), August 11, 1909. Coll. Culp. I. U. Myc. Herb. 2655. Distinguished from *C. rosicola* Pass. by its much larger conidiophores and spores, and from *C. rosigena* Tharp, by its smaller spots and thicker spores.

PHYLLOSTICTA INDIANENSIS *sp. nov.*

Spots very small, 0.5 to 2 mm. (mostly about 1 mm.), rather evenly distributed over the surface of the leaflets, circular, or sometimes irregular, above becoming pale with purple border, below not conspicuous but may appear buffy-brown. Pycnidia few, 1 to 4 (usually 1 or 2) in the center of each spot, almost wholly epiphyllous, 50 to 90 (mostly about 75) microns in diameter, with distinct pores about 12 microns in diameter. Spores ovate to elliptical, 12 to 17 by 6 to 8 microns (mostly 12.5 by 7.5), and surrounded by a dense gelatinous envelope 2 to 3 microns thick.

On *Rosa setigera* Michx., I. U. campus (Old Forest Place), October 1, 1917. I. U. Myc. Herb. 3855. The outstanding characters of this species are the very small spots (which resemble closely those of *Septoria Rubi* West. on various *Rubus* species), the few pycnidia, and the granular thick gelatinous coated spores.

PHYLLOSTICTA ROSAE-SETIGERAE *sp. nov.*

Spots 1 mm. to 2 cm. in diameter, walnut-brown, usually with a darker (chestnut-brown) center, giving a bird's eye appearance, broad dark-purple margins, circular, or semi-circular where they are noticeably arranged around the edges of the leaflets. Pycnidia mostly epiphyllous, very numerous, rather prominent, rupturing the epidermis, distributed over the entire spot, but showing in concentric rows in the newer parts of the spot, spherical, 75 to 100 microns in diameter, pores distinct. Spores numerous, hyaline, spindle-form to tapering cylindric, usually with one or two small guttulae, 8 to 12 by 2 to 3 microns.

On leaves of *Rosa setigera* Michx., Monroe County, Indiana, October 16, 1916. I. U. Myc. Herb. 3714; August 23, 1920. I. U. Myc. Herb. 3804. The former specimens showed smaller, less defined spots than did the latter where the plants were being defoliated at time of collecting. *Phyllosticta erratica* E. & E., which forms characteristic marginal spots on leaves of the widely separated host, *Ulmus*, has been recorded by one author on *Rosa* species. This, however, is quite distinct from our species, differing particularly in its hypophyllous pycnidia and smaller globose or ellipsoid spores. From *P. Rosae* Desm., it differs in color of spots, size of pycnidia, and shape and size of spores.

CONCERNING THE REACTION OF CERTAIN FUNGI TO VARIOUS WAVE LENGTHS OF LIGHT.

C. L. Porter and H. W. Bockstahler, Purdue University.

Since fungi lack chlorophyll, their needs with regard to light are quite different from those of green plants. While light is not needed for photosynthesis, yet it forms an element of the environment of the great majority of the Eumycetes. It has long been considered true that light, especially sunlight, is detrimental to the complete development of a fungus. Hence, one who hopes to avoid mildews and musty odors opens the house to the sun and air. On the other hand many fungi apparently will not complete the cycle of their development in complete darkness. Thus, many Coprophilous fungi remain sterile in darkness, producing their fruiting bodies only when exposed to direct sunlight. Many of this group of fungi exhibit positive phototropic responses. The sharpshooting of Pilobolus is especially famous. Apparently with most fungi vegetative development proceeds as rapidly in the dark as in the light. Many produce their sporangia or conidia regardless of the presence or absence of light. The higher Basidiomycetes, however, prefer illumination for sporophore production. Many of this group produce sporophores only upon light exposure, although such exposure needs to be brief in many cases.

An attempt to catalogue and analyze light effects is not an easy task. White light as it comes to us from the sun is a composite of many wave lengths. Furthermore, we now know that there are light waves and other vibrations of the ether which though not immediately evident to our physical senses nevertheless exert a most profound influence upon living processes.

The effect of light upon the growth of fungi in cultures was given as a problem to an advanced class in the "Physiology of the Fungi" at Purdue University. This class developed a technique, made preliminary observations, and achieved some interesting results. Their results are herewith summarized.

The problem had two phases: A. Growth of fungus in continuous light, continuous darkness, alternate light and darkness. B. Growth of cultures under continuous illumination through spectrally pure glass filters. Cambosco filters were used.

Observations were made concerning rate of growth, spore production, hyphal modifications, changes in color, zoning, etc.

This work demonstrated that fungi may be made to vary in spore production and vegetative development with changes in the quality and the intensity of the light source. These results have since been elaborated by Cooper and Porter[1] in a recent paper.

[1] Cooper, D. C. and C. L. Porter. Phytopathology. *18*:881-899. 1928.

Since these preliminary investigations have indicated that fungi vary considerably in their reactions to light, the authors have begun an elaborate series of investigations in an effort to classify and interpret these phenomena. The results which follow are in the nature of a report of progress.

Our present research involves but two phases of this very large and intricate problem. (a) The effect of various wave lengths of light confined to the visible spectrum. (b) The effect of the extremely short and non-visible radiations of the ultra violet.

The use of colored glass filters spectrally pure enabled us to investigate the reaction of fungi under different portions of the visible spectrum. Filters used were those sold by the Cambridge Botanical Supply Co., under the name of Cambosco spectro-radioscopic glass filters. In the experiment here recorded the following filters were used: No. I transmitting full spectrum except yellow. No. II transmitting primary blue. No. III transmitting only infra red. No. IV transmitting red and yellow only. No. V transmitting blue-green.

The filters were placed in the bottoms of light proof boxes, in which was suspended a tungsten filament electric globe of appropriate candle power.

The experiment was carried on in an especially constructed dark room in the basement of the greenhouse. Each set of exposed plates was separated from the others by screens of heavy dark building paper so that it was impossible for any cross lighting to take place. The plates were exposed with the lids of the petri plates in place. Removal of the lids caused rapid drying of the media and such practice was considered unnecessary.

It was found that the filters not only varied in the quality of the light they transmitted but also in the quantity. The amount of light transmitted by the several filters was carefully measured and equality in quantity of illumination was secured by varying the candlepowers of the lights and the distance of the lighting apparatus from the exposed plates.

It was realized that temperature as well as light affects fungous cultures. Temperature records of the various exposures were kept and in no case did the temperature vary to an appreciable degree.

The fungi used were: *Colletotrichum lindemuthianum, Cephalothecium roseum, Sclerotium rolfsii, Sclerotinia* sp.

It is evident from our experiments that in the wave lengths of light to which the four cultures were subjected little marked difference is to be noted in any of the points upon which particular observation was made. There is a tendency for the cultures to grow less rapidly in any of the lights than in darkness. This inhibition was especially marked when filter No. V was used. The most sensitive portion of a culture to light is apparently the aerial hyphae and differences, often quite marked, are to be noted. Such variations in development of aerial hyphae often change the entire macroscopic aspect of the colony. Only two of the fungi used, *C. lindemuthianum* and *C. roseum*, produce spores in culture. Of these, the latter was quite constant in sporulation no matter what the light, but the former shows a range of sensitivity in this particular

in varying wave lengths of light. Malformations of hyphal filaments were produced under certain filters. Such malformations are very interesting and will be the subject of further intensive study. They either indicate some physiological change within the fungus or a possible tendency to mutate.

The second portion of our research dealt with the effect of ultra violet radiations on fungus cultures. The same fungi used in the previous experiment were used here. Ultra violet radiations were secured from a Cooper Hewitt quartz mercury arc.

The half-plate method of exposure was used. The lid of the plate was removed and half of the fungus colony was covered with the black paper in which photographic plates are wrapped. The distance of exposure was 60 cm. Length of exposure varied from five seconds to 60 minutes. A certain number of cultures were exposed after a filter which permitted only wave lengths between 363-365 was inserted into the machine. The remaining cultures were exposed to the full range of the ultra violet radiations.

Two marked changes are produced by the ultra violet, viz., inhibition of growth and collapse and probably death of the aerial hyphae. Relatively short exposures will produce these effects, which are quite visible to the naked eye. In addition to these effects spore formation is inhibited sharply in *Cephalothecium* but on the other hand slightly accelerated in the case of *Colletotrichum*. Stevens[2] has recently demonstrated these same effects and in addition claims that ultra violet affects quite materially the production of sexual fruiting bodies in the fungus used. The fact that the filter prevented any of the visible effects noted in its absence would indicate that only wave lengths between 395 and 410 are harmful to fungus growth.

In order to discover whether the fungi exposed to ultra violet radiations had been killed or merely inhibited, transfers were taken from the exposed and unexposed portions immediately after radiation.

With the exception of *Sclerotinia* sp. cultures exposed to the radiations of ultra violet for as long as an hour are not killed, as their transfers grow in a normal fashion. Sclerotinia is not killed in a half an hour of radiation. This fact is quite remarkable as the collapsed condition of the aerial hyphae would indicate that this portion of the fungus had been killed. It is evidently clear from our work that the hyphae lying on the surface of the medium or imbedded in it are not so quickly or easily affected by the ultra violet radiations.

While we must regard this investigation as too fragmentary to draw any very definite conclusions, yet we feel quite sure that from our observations to date the following statements are justified: 1. Fungi are extremely sensitive to light changes. 2. The quality as well as the quantity of light affects the growth and development of fungi. 3. It is apparent that ultra violet wave lengths cause greater material changes than do those of the visible spectrum. 4. While the ultra violet affects the aspect of colonial development, yet the actual killing effect is not marked.

[2] Stevens, F. L. Science N. S. *68*:514-515. 1928.

THE PERICYCLE IN THE ROOT OF EQUISETUM.

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The researches of Van Tieghem (1) on the root of Equisetum led him to conclude that a pericycle is entirely absent. Campbell (2) is of the same opinion. Both of these investigators state that the endodermis is two cells in thickness but that the outer cell develops characteristic Casparian thickenings. But the so-called inner endodermis resembles a pericycle in appearance and position, gives rise to secondary roots and is continuous with the pericycle of the stem. Its origin is definitely cortical as Van Tieghem and Campbell have shown and this appears to be the only reason for not giving it the name of pericycle. Their interpretation satisfies the definition that the endodermis is the innermost layer of the cortex but is inconsistent in that the pericycle of the stem is then continuous with the endodermis of the root. Just where the stem pericycle ends and the inner endodermis of the root begins becomes a purely arbitrary statement.

Recent investigations on the origin of tissues have shown that in some cases it is impossible to consider the endodermis as the innermost layer of the cortex and the pericycle as the outer boundary of the stele. Chang (3) working on *Pteris aquillina* and Conard (4) on *Dicksonia punctilobus* have found that the endodermis is stelar. Schoute (5) and Barratt (6) on Hippuris and Johnson (7) on *Equisetum scirpoides* have shown that not only the endodermis but from one to several layers of the cortex as well is of stelar origin. The morphologist now may take one of two courses, either recognize the tissues in question solely on their morphological and physiological differentiation or entirely on their origin. It is the latter criterion which has largely been used in the past.

If, in the root of Equisetum, the pericycle is to be eliminated on the grounds that it is cortical in origin, then, the endodermis is most certainly lacking in the rhizome of *Pteris aquilina* and *Dicksonia punctilobus*. In fact one is not only obliged to consider the endodermis as absent but must also regard the outer layer of the pericycle as developing Casparian thickenings. In the stem of Hippuris and Equisetum the situation is even more confusing because there the stele is terminated by a layer of cells usually regarded as cortex but which may now be called pericycle. The presence of a layer of cells with Casparian thickenings just inside the pericycle (should it be given that name) is difficult to explain.

Thus, it seems unwise to classify tissues solely on their origin, especially when so many variations are coming to light in recent research. The other alternative is to consider morphological and physiological differentiation as the criterion for classifying tissues regard-

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

less of their origin. If this is done the difficulties which arise when the endodermis is considered as the innermost layer of the cortex and the pericycle as the outer boundary of the stele are avoided. Therefore, it seems wise to apply the term pericycle to the so-called inner endodermis in the root of Equisetum. By so doing the terminology of the tissues of the root is harmonized with that of the stem.

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SODIUM CHLORATE AS A HERBICIDE.[1]

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The aim of most experimenters with chemical weed killers has long been to find a plant poison capable of penetrating and destroying the creeping underground parts of such persistent perennials as Canada thistle, quack grass and wild morning glory. There is a strong demand on the part of farmers for a chemical of this type since it has been demonstrated that a piece of the creeping root of quack grass or Canada thistle but a half inch in length will readily start new infestation and farmers have experienced serious losses in labor, decreased yields and the lowering of land values due to infesting large areas by means of root pieces carried from small patches on cultivating implements.

After repeated failures with arsenicals, oils and other chemicals, experimenters seem to have been achieving their aims with sodium chlorate. The first experimental work with this material started in Germany and the work was continued under American conditions by the Cornell Agricultural Experiment Station with Canada thistle,[1] the Kansas Agricultural Experiment Station with field bindweed,[2] *Convolvulus arvensis*, and the Purdue University Agricultural Experiment Station with quack grass.[3] Thus three of the major weed problems have been partly solved, particularly the important phase presented by small areas of infestation, by the use of sodium chlorate.

In addition to the work upon quack grass, a number of sodium chlorate tests on other species of weeds have been conducted by the writer. An important economic problem on Indiana farms is the presence of poison ivy, which in many instances materially lowers the selling value of the land. In order to test the value of sodium chlorate against this pest, five fence posts heavily overgrown with poison ivy on a farm near the Clay Township School in Howard County were treated with a sodium chlorate solution on December 15, 1927, in such a manner as to thoroughly saturate the ivy. Inspection at regular intervals failed to reveal any evidence of sprouting during the growing season of 1928. An examination of the underground parts showed that the tissues were brown and dead. Poison ivy left as a check thrived throughout the season. A practical test was made on the Purdue experimental farm located near Bedford on which a heavy growth of poison ivy located in an orchard was saturated with sodium chlorate during the early part of August, 1928. Three weeks later the ivy was apparently completely dead and no further evidence of life could be seen during the remainder of the growing season. The material was applied with a power sprayer.

[1] Contribution from the Department of Botany, Purdue University Agricultural Experiment Station.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

At the same time a heavy growth of buck brush, *Symphoricarpos symphoricarpos* (L.) MacM., was saturated with sodium chlorate applied with a power sprayer. Apparently complete killing was secured since no further evidence of sprouting was noted during the remainder of the growing season although the buck brush retained its green color for a longer period after spraying than any other weed so treated observed to date. For observations on the effect of the spray upon buck brush the writer is indebted to H. J. Reed, assistant director of the Purdue University Agricultural Experiment Station, in charge of the Bedford experimental farm. Buck brush is an important pasture weed problem in southern Indiana.

A single test with dry sodium chlorate was made against the purple barberry, *Berberis vulgaris* L., in Miami County. Two pounds of dry sodium chlorate were piled at the base of a healthy specimen approximately six feet in height on July 12, 1928. The plant was dead a week later and no evidence of sprouting could be found during the remainder of the growing season of 1928 nor during April 1929.

Upon the recommendation of Purdue University, farmers in all parts of Indiana have been using sodium chlorate against Canada thistle, quack grass and poison ivy with uniformly successful results where correctly applied. Demonstrations have been conducted in ten counties and the sprayed areas regularly inspected and in every instance a 95% to 100% kill has been secured with a single application. For example a patch of Canada thistles on a farm in White County was thoroughly saturated with sodium chlorate on July 20, 1928. An inspection on September 4 revealed no evidence of sprouting. On the Harry Matlock farm near Kokomo a patch of quack grass containing approximately five square rods and two fence posts supporting a heavy growth of poison ivy were treated on July 1. A careful examination of the roots and tops on September 11 revealed that the tissues were brown and dead, a complete kill having been secured. These are instances of numerous similar tests made in various parts of the state.

From experience and experiments made with sodium chlorate to date it seems that the material may be applied at any time of the year after the plants have made their maximum top growth, the early bloom stage being perhaps best for uniform results. Such failures as have been observed have been due mainly to lack of thorough saturation of the tops, to careless application, to mowing the weeds before using the chlorate or to applying in immature stages. For economy of material and best results the chlorate should be dissolved in water at the rate of one pound per gallon, the strength used in the tests here recorded. Where trouble in securing complete dissolving of the chemical is experienced the use of warm water gives prompt results, but this is not ordinarily necessary. Sodium chlorate during the past season cost between seven and eight cents per pound delivered in Indiana when purchased in 112 pound steel drums.

The main disadvantage of sodium chlorate is its inflammable character. When proper precautions are taken, namely mixing the chemical in the open, washing clothes upon which the chlorate has dried and keep-

ing fire from matches, tobacco and other sources away from clothes and shoes incrusted with the material, there is little danger. Only one case of chlorate fire has been reported in Indiana, an instance in which a White County man who had sprayed weeds with a sodium chlorate placed his shoes on a warm stove. In a short time the shoes broke into flames.

Sodium chlorate is also slightly toxic and livestock, particularly salt hungry animals, should not be allowed to graze on treated vegetation until after the first rainfall. No reports of livestock losses as a result of chlorate poisoning, however, have been reported in areas where the material has been used in large quantities. One doubtful case, the loss of a cow, occurred in Tippecanoe County under circumstances that may have involved chlorate poisoning but in this instance the animal seemed to have been improperly salted. It is believed that the use of sodium chlorate is relatively free from danger to farm animals, another point of superiority over sodium arsenite which has been the most widely used of chemical weed killers.

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2. Latshaw, W. L. and J. W. Zahnley. Experiments with sodium chlorate and other chemicals as herbicides for field bindweed. Jour. Agr. Res. 35:8:757-767. 1927.

3. Hansen, Albert A. Eradicating quack grass with sodium chlorate. Jour. Amer. Soc. Agron. 20:10:1120-1123. 1928.

INDIANA PLANT DISEASES, 1927.[1]

MAX W. GARDNER,[2] Purdue University Agricultural Experiment Station.

This is the ninth[3] of a series of annual summaries of the plant disease situation in the state. No claim for completeness is made.

The weather during the 1927 season, as shown in the graphs in figure 1, was characterized by an early spring, a warm March and April, abnormally cool weather during May, June, July, and August,

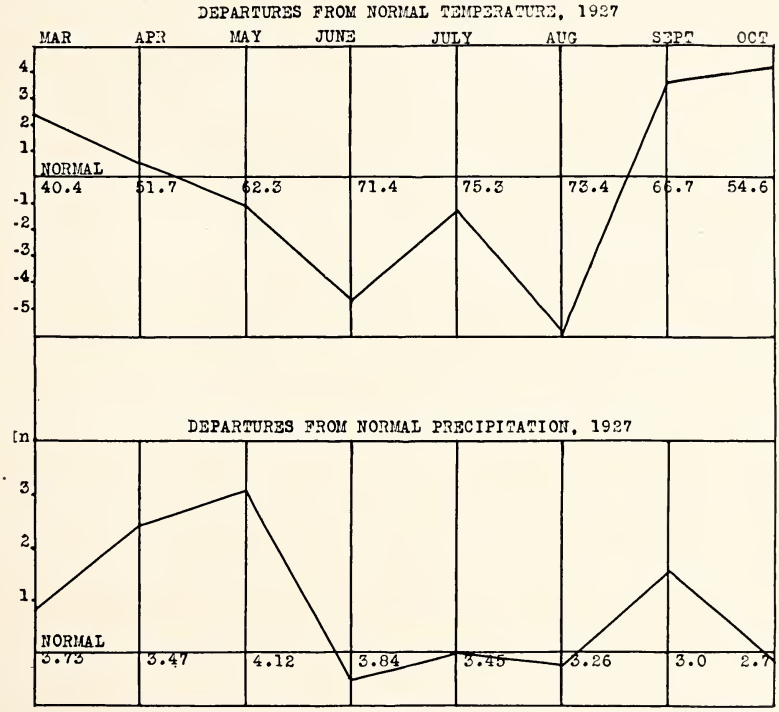

Fig. 1—Departures from normal temperature and precipitation based on monthly averages supplied by J. H. Armington in Climatological Data.

[1] Contribution from the Department of Botany, Purdue University Agricultural Experiment Station.

[2] The writer wishes to acknowledge the co-operation of H. S. Jackson, E. B. Mains, G. N. Hoffer, J. B. Kendrick, F. C. Gaylord, W. E. Leer, C. T. Gregory, L. C. Cochran, F. P. Cullinan, J. F. Trost, K. E. Beeson, E. J. Kohl, B. A. Porter, Leslie Pierce and H. F. Dietz.

[3] Proc. Ind. Acad. Sci. 1919:135-156. 1921; 1920:187-208, 1921; 1923:163-211, 1924; 1924:297-313, 1925; 1925:237-257, 1926; 1926:231-247, 1927; 1927:411-426. 1928.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

very warm weather in September and October, and high rainfall in the spring and fall. The frequent rains in the spring favored apple scab, blotch, and rust, peach leaf curl, cherry leaf spot, and wheat bunt, scab, and leaf rust. The summer was too cool for the Fusarium wilt diseases and apple bitter rot, and the rains were frequent enough to favor peach bacterial spot, anthracnoses in general, powdery and downy mildews, and fungous leaf spots such as Septoria leaf spot of tomato.

DISEASES ARRANGED ALPHABETICALLY BY HOSTS.

Alfalfa. Leaf spot caused by *Pseudopeziza medicaginis* was more prevalent than usual. Van Hook[4] reports it severe. Downy mildew (*Peronospora trifoliorum*) was found in Jackson County on April 19. A surface blackening of the stems of Grimm alfalfa caused by *Pseudomonas medicaginis* was found by M. O. Pence in Starke County, late in May. A pitting of the tap root of unknown cause and apparently identical with that described by Stewart, French, and Wilson[5] in 1908 and Weimer[6] in 1927, was brought in from Kosciusko County, in May.

Apple. Scab, caused by *Venturia inaequalis*, was exceedingly severe this year because of the frequent and heavy rainfall during the infection period in April and May. McCown found foliage infection on Grimes at Lafayette as early as May 6 and severe foliage and fruit infection occurred on Grimes, Jonathan, Wealthy, and especially on Rome. Calyx-lobe and pedicel lesions, as well as fruit lesions, were found in abundance in late May and early June. At Paoli, fruit infection on Rome was abundant in trees not receiving the pink spray. Late season infection produced the smooth black lesions which develop in storage.

Blotch, caused by *Phyllosticta solitaria*, was much worse than it has been since 1922, owing to the frequent rains of April and May. Kohl[7] found by the use of potted trees that the first infection at Mitchell in southern Indiana occurred 5 days and the last infection 8 weeks after petal fall (Apr. 25) and that infection occurred during 15 out of the 17 rains during this period. At Lafayette he found that the first infection occurred 3 days and the last infection 7 weeks after petal fall (May 7) and that infection occurred during 18 out of the 27 rains during this period. Cankers were found on Golden Winesap at Vincennes and on Hubbardston at Seymour, two varieties not previously listed as susceptible in Indiana. Cankers and light fruit infection were found on Delicious and leaf and fruit infection was found on Transparent. McCown found fruit infection on Oldenburg as early as June 1, near Vincennes. The degree of canker infection on Kansas-grown seedlings is shown by the fact that on one seedling examined in a nursery, 27 out of the 29 leaf scars were infected.

[4] Van Hook, J. M. Indiana Fungi-X. Proc. Ind. Acad. Sci. 1927:365-371. 1928.

[5] Stewart, F. C., French, G. T. and Wilson, J. K. Troubles of alfalfa in New York. N. Y. (Geneva) Agr. Exp. Sta. Bul. 305:172-243. 1908. (p. 233).

[6] Weimer, J. L. Observations on some alfalfa root troubles. U. S. Dept. Agr. Dept. Cir. 425:1-9. 1927.

[7] Kohl, Edwin J. The cycle of infection in apple blotch. Abs. in Phytopath. 18: 145. 1927.

Frog-eye leaf spot, caused by the black rot fungus, *Physalospora malorum*, was also extremely prevalent early in the season. Heavy infection was noted on Grimes, Transparent, Jonathan, Wealthy, Oldenburg, and especially on Rome. The Bordeaux blotch sprays prevented frog-eye leaf spot in a young Oldenburg orchard in which the trees receiving only the scab sprays were badly infected.

Rust (*Gymnosporangium juniperi-virginianae*) was also favored by the spring rains, and abundant foliage infection occurred on Rome and Jonathan in southern Indiana. Light leaf infection was noted on Benoni, a variety not included in the list of susceptible varieties in the 1924 report, and fruit infection was found in the Rome variety. Telial spore horns were noted on cedar galls in Jackson County on April 19, when apples were in full bloom, and near Lafayette on May 8.

Bitter rot, caused by *Glomerella cingulata*, was reported to be serious in the orchard in Warrick County where it has occurred annually for many years.

Fire blight, caused by *Bacillus amylovorus*, was very mild this year. It was noted on Jonathan, Transparent, and Benoni in southern Indiana. Fruit infection occurred on Transparent. A serious outbreak occurred near Lafayette in old sweet apple trees near pear trees, and some infection also occurred in young Wealthy trees in another orchard. In an inoculation test on Grimes trees McCown[8] found that a Bordeaux spray applied in the full bloom stage greatly decreased the amount of blossom blight.

Nailhead or blister canker, caused by *Nummularia discreta*, was found on Norwestern in Fountain County and on Transparent in Orange County. Sooty blotch (*Gloeodes pomigena*) was reported to be severe on the Golden Delicious variety in Knox County.

The fruit rot caused by *Phytophthora cactorum* was found early in the season (June 7) on many fallen fruits under Grimes trees in the same orchard near Lafayette in which the disease has been found nearly every season. One small green fruit on a lower limb was also infected. This disease was also found in October on Rome fruit from the same orchard. Cooper[9] found that this fungus invades the fruit through the lenticels and that zoospores may cause infection.

A destructive outbreak of pink rot (caused by *Cephalothecium roseum*) apparently following surface bitter pit occurred at Lafayette in Grimes fruit picked late in September and held about two weeks in uncooled storage (fig. 2). In general the lesions were independent of scab spots and insect wounds. The lesions varied from 2 to 15 millimeters in diameter and were sunken and brown, usually with a light tan center and an irregularly circular or lobed margin. On green fruits each lesion was surrounded by a yellow halo. Forty-six lesions on 10 fruits were cultured and 20 yielded pure cultures of *C. roseum*, while the remainder, most of which were small lesions, remained sterile.

[8] McCown, Monroe. Spraying for the control of fire blight in the apple. Trans. Ind. Hort. Soc. 1927:129-133. 1928.

[9] Cooper, Delmer. Paragynous antheridia of Phytophthora spp. Abs. in Phytopath. 18:149-150. 1928.

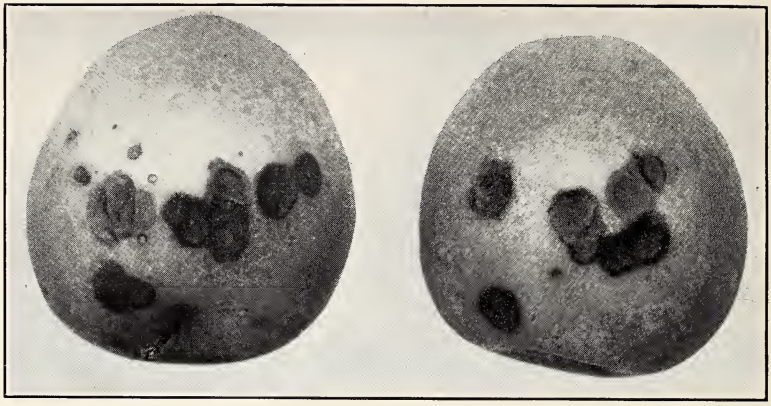

Fig. 2—Pink rot (*Cephalothecium roseum*) infection on Grimes fruit apparently following surface bitter pit and independent of scab spots.

Consequently, it seems likely that the pink rot had resulted from secondary invasion of a surface type of the non-parasitic bitter pit. This type of bitter pit was also found on Rome fruit from the same orchard and these lesions, when cultured, proved to be sterile.

The fruit spot and rot caused by *Sporotrichum malorum*[10], first described in the 1925 report as a surface spotting of Grimes, was found causing heavy losses in a storage house at Seymour. Out of 200 bushels of Ben Davis, 45 had been culled out as a total loss due to this disease, some of which was also found in Gano and Winesap. Brown bark spot or measles, a non-parasitic trouble, was found in Clark and Lawrence counties.

Apricot. Canker, caused apparently by *Nectria cinnabarina,* was sent in from Montgomery County.

Bean. Bacterial blight, caused by *Bacterium phaseoli,* was less destructive than usual, due to the cold weather. Mosaic was widespread as usual. Anthracnose, caused by *Colletotrichum lindemuthianum,* occurred in the home gardens late in the fall. Rust (*Uromyces appendiculatus*) was found killing the older leaves in a market garden planting of Kentucky Wonder pole beans in Marion County late in September.

Angular leaf spot, caused by *Isariopsis griseola,* was found by L. E. Compton on the Burpee's Stringless Greenpod variety in a garden at Lafayette late in September. The fungus was sporulating profusely on the under surface of each leaf lesion (fig. 3) and was readily isolated in pure culture. Pod lesions were also found (figure 3). These differed from anthracnose in being a uniform dark grayish brown in color with a diffuse margin and a center only slightly sunken. In the center of each lesion were conspicuous, black, projecting fascicles of sporophores.

[10] Gardner, Max W. Sporotrichum fruit spot of apple. Abs. in Phytopath. 18:145. 1928.

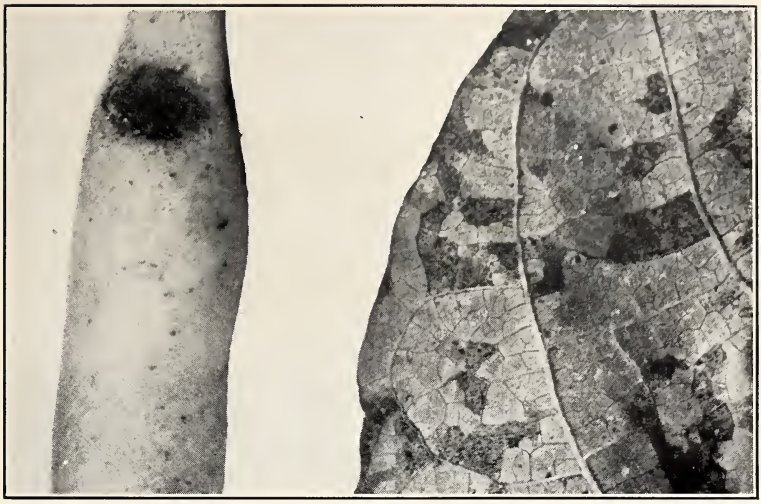

Fig. 3—Leaf and pod lesions of bean angular leaf spot caused by *Isariopsis griseola* (Enlarged x 2).

Beet. Leaf spot caused by *Cercospora beticola* was found in market gardens.

Blackberry. Anthracnose, caused by *Plectodiscella veneta,* was very severe. Specimens received from Johnson and Lawrence counties showed heavy infection on young canes, fruiting spurs, and leaves; so severe, in fact on leaf petioles, petiolules and veins as to blight leaflets outright. Young fruiting spurs were likewise being killed. Orange rust (*Gymnovonia peckiana*) was sent in from Montgomery County and mosaic from Elkhart County.

Brussels Sprouts. Leaf spot, caused by *Alternaria brassicae,* was found near Lafayette in November.

Cabbage. Yellows, caused by *Fusarium conglutinans,* was much less severe than usual, owing to the cool weather. Black rot, caused by *Bacterium campestre,* and black leaf spot, caused by *Alternaria brassicae,* were found on young plants in June. On Chinese cabbage, gray leaf spot, caused by *Alternaria herculea,* was found in Steuben County in October.

Cantaloupe. Leaf blight, caused by *Macrosporium cucumerinum,* was found by Trost in Marion County, but was much less destructive than it is in hot seasons.

Carrot. Leaf spot, caused by *Cercospora apii carotae,* was found in Marion County in September and near Lafayette in November.

Celery. Early blight, caused by *Cercospora apii,* occurred in Boone County. Late blight, caused by *Septoria apii,* was extremely destructive

on the late crop in Noble and Steuben counties. In a field visited late in October the exposed leaves of the banked celery were generally blighted and the pycnidia were so abundant that the lesions were conspicuously blackened.

Cherry. Owing to the spring rains, leaf spot caused by *Coccomyces hiemalis* was more severe than it has been during the last nine years and caused complete defoliation of many trees before the fruit was harvested and a noticeable loss of flavor in the fruit. The disease was statewide, and was definitely recorded from nine counties. The disease was found very destructive in a nursery on sweet cherry stock, despite Bordeaux sprays, and on Mahaleb seedlings from France planted at a distance from other cherry nursery stock. Specimens sent in from an orchard in Lawrence County in May showed that the young fruits were being killed by numerous pedicel lesions, in which spores were found.

Clover. Sooty spot, caused by *Polythrincium trifolii,* was found on white clover near Lafayette early in May. Powdery mildew was generally present on red clover. Mains found anthracnose very destructive and reports that *Gloeosporium caulivorum* causes the more destructive anthracnose in southern Indiana while *Colletotrichum trifolii* is the cause of the form more serious in northern Indiana. Mains[11] has published a detailed account of the Indiana clover diseases and the varietal susceptibility to these including anthracnose, powdery mildew, bacterial spot, Macrosporium leaf spot, rust, and mosaic.

Corn. Hoffer, Trost, and St. John estimated the loss due to Fusarium root and stalk rots at 3 per cent, Fusarium ear rot, 0.5 per cent, and Diplodia ear rot, 2.5 per cent. Duddleston reported smut (*Ustilago zeae*) less prevalent than usual and Mains reported the same for rust (*Puccinia sorghi*). Bacterial wilt, caused by *Bacterium stewartii,* was found on sweet corn in Jackson County and at Lafayette. Trost found foot rot, caused by *Ophiobolus heterostrophus,* at Lafayette late in June.

Cowpea. Mosaic occurred in experimental plots at Lafayette.

Cucumber. Powdery mildew (*Erysiphe cichoracearum*), angular leaf spot, caused by *Bacterium lachrymans,* and mosaic were noted in greenhouses in Marion County in May. Bacterial wilt was noted in Madison County in September.

Currant. Anthracnose, caused by *Pseudopeziza ribis,* caused severe defoliation in June in commercial plantings. In a planting at Lafayette containing a number of varieties, the variety London Market showed marked resistance to anthracnose. In this planting, leaf spot, caused by *Mycosphaerella grossulariae,* was less destructive than anthracnose.

Dewberry. Leaf spot, caused by *Mycosphaerella rubi,* was found in June near Lafayette.

Ginseng. Blight, caused by *Phytophthora cactorum,* was found in a garden at Lafayette in June.

[11] Mains, E. B. Observations concerning clover diseases. Proc. Ind. Acad. Sci. 1927:355-364. 1928.

Gooseberry. Anthracnose (*Pseudopeziza ribis*) caused serious defoliation early in June at Lafayette, and leaf spot, caused by *Mycosphaerella grossulariae*, was worse on this host than on currants.

Grape. Downy mildew (*Plasmopara viticola*) was found at Lafayette in June and on wild grapes in October.

Horseradish. Leaf spot, caused by *Cercospora armoraceae*, was found at Lafayette in November.

Lettuce. Downy mildew (*Bremia lactucae*), Botrytis rot, drop caused by *Sclerotinia libertiana*, and Rhizoctonia stem rot were observed in Marion County greenhouses in April.

Oats. Mains estimated the loss due to crown rust (*Puccinia coronata*) at 5 per cent and reported the presence of scab, caused by *Gibberella saubinetii*.

Onion. Smut (*Urocystis cepulae*) has occurred commonly in the small crop grown for sets and this year the first evidence was obtained of its occurrence in the important commercial bulb crop when it was found in a bundle of seedlings sent in from Steuben County on June 2.

A survey of the onion crop in northeastern Indiana was made late in October when the onions were being put in storage. Yellow onions, which constitute the bulk of the crop, and red onions were free from neck rot and smudge, and were subject to reduction in quality only from sunscald that occurred during hot weather after digging and to a limited extent from blemishes of the outer scale such as silver spot, caused by a Penicillium, blotch (cause unknown), and a non-parasitic black stain. These blemishes were most objectionable on onions that had been in wet soil because the discolored outer scales or fragments of these adhered to the underlying bright scales and such onions could not be easily cleaned. There was also some sun greening on yellow onions.

The disease situation in white onions, which are grown to a less extent than the colored varieties, was found to be entirely different. Smudge, caused by *Colletotrichum circinans*, was very prevalent, and the three Botrytis neck rots recently differentiated by Walker[12] were found causing heavy losses on the grading tables. Most conspicuous and prevalent among these was the small sclerotial neck rot (fig. 4, B), caused by *Botrytis squamosa*, which, curiously enough, was generally termed "smut" by the growers. The flattened black sclerotia showing through the outer scale were indeed suggestive of smut symptoms. Mycelial neck rot (fig. 4, A.), caused by *Botrytis byssoidea*, and gray mold neck rot, caused by *Botrytis allii*, were also very abundant and, in their effects, more deep-seated and destructive than the small sclerotial type. There was also some blue mold rot. Rather large pink blotches with which a Fusarium was associated were found on the outer scales rather commonly. Sun scald was not as prevalent as in the colored varieties, but sun greening was very common. Sun scald lesions in all varieties were frequently invaded by various fungi.

[12] Walker, J. C. Botrytis neck rots of onions. Jour. Agr. Res. 33:893-928. 1926.

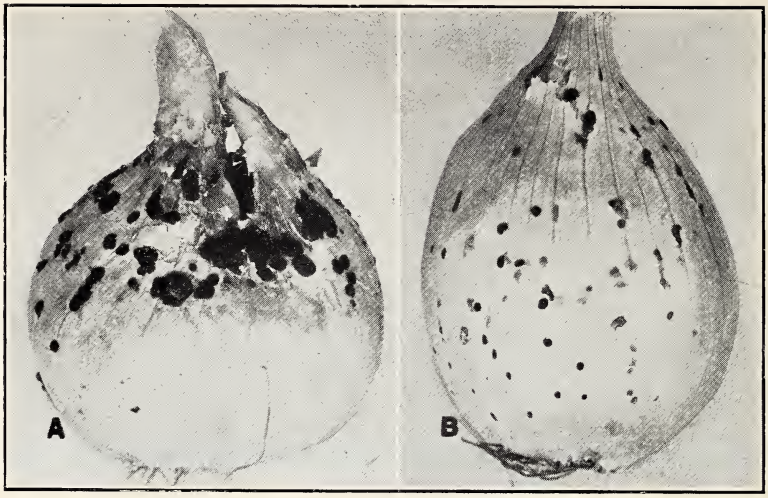

Fig. 4—Neck rots of white onions. A. Mycelial neck rot caused by *Botrytis byssoidea*. B. Small sclerotial neck rot caused by *Botrytis squamosa*.

Parsnip. Leaf spot caused by *Cercospora pastinaceae* was found in November at Lafayette.

Peach. Leaf curl, caused by *Exoascus deformans*, was somewhat worse than usual, presumably because there was a warm period late in February and in many cases the spray was applied too late. Leaf curl was first observed by Pierce on April 6, in Knox County. Fruit lesions were found at Evansville. Fruit infection of scab, caused by *Cladosporium carpophilum*, was noted in Knox County. Bacterial spot, caused by *Bacterium pruni*, was worse than it has been since 1923 and caused heavy defoliation in May and June. Considerable fruit infection also occurred. Pierce[13] at Vincennes has found the Hale variety more susceptible to fruit infection than Elberta.

Because of the frequent rains and the hail wounds and growth cracks, brown rot, caused by *Sclerotinia fructicola*, was very serious this year in Posey County according to Gaylord and caused the rejection of several carloads. Pierce (l. c.) reported brown rot of the fruit much worse at Vincennes than in 1925 or 1926. Late in May he found infection on young green fruits of the Hale, Elberta, and Redbird varieties and found twig cankers a rather common result of blossom blight. Dietz found the same type of twig infection in Lawrence County. Pierce also found old cankers where mummies from the 1926 crop had been attached. The first apothecia were found by Pierce under a seedling tree on March 22 and in one orchard he counted 96 clusters of apothecia under one seedling tree. Pierce found die-back, caused by *Valsa leucostoma*, following old brown rot cankers.

[13] Pierce, Leslie. Brown rot and shot-hole. Trans. Ill. State Hort. Soc. 61 (1927): 405-418. 1928.

Pear. In a five-year-old orchard in Putnam County, a bad infection, probably of 1926 origin, of fire blight, caused by *Bacillus amylovorus*, was confined to a small area along one side of the orchard not far from a wooded gully in which an old seedling apple tree containing blight cankers was found. The orchard consisted mostly of Bartlett trees and all of the fire blight was in this variety. In this orchard, the non-parasitic disease known as measles or brown bark spot was found prevalent on young twigs of Flemish Beauty trees, of which there were three rows. None was noted on the Bartlett, Anjou, or Clapp's Favorite varieties.

Pepper. Mosaic was common in market gardens in Marion County.

Plum. Plum pockets or bladder plum, caused by *Exoascus pruni*, was sent in from Daviess County, black knot, caused by *Plowrightia morbosa*, from Boone and Bartholomew counties, and brown rot, caused by *Sclerotinia fructicola*, from Marion County.

Potato. Late blight (*Phytophthora infestans*) tuber infection occurred in DeKalb, Tipton, and Montgomery counties and for the first time in at least nine years caused considerable loss. Early blight, caused by *Alternaria solani*, was noted in Clinton County. Scab, caused by *Actinomyces scabies*, and black scurf (*Rhizoctonia solani*) were of general occurrence. Black leg, caused by *Bacillus phytophthorus*, occurred in the early crop in Marion and Bartholomew counties. Silver scurf, caused by *Spondylocladium atrovirens*, was found on Irish Cobblers. Leaf roll was, as usual, the most important disease in the late crop, and mosaic was of less importance. In the common Indiana varieties, mosaic[14] spreads much less rapidly than leaf roll.

Radish. Black-root, caused by *Aphanomyces raphani*, occurred in May at Lafayette.

Raspberry. Anthracnose, caused by *Plectodiscella veneta*, was worse than usual, because of the frequent spring rains, and was recorded from 11 counties. Red as well as black varieties were severely affected. On black varieties infection occurred on leaves, fruit spurs, and even on the fruit. Late in June, new lesions were abundant on the tips of the shoots, a circumstance which indicated that new infection had occurred much later in the season than is usual. Abundant infection was found in a new planting well isolated from old patches, even though the old stubs on the transplants had been cut off below the surface of the soil. In a badly diseased plantation near Lafayette, the variety Plum Farmer showed good resistance as judged by the vigor of the old canes and the freedom from current season infection. Leaf spot, caused by *Mycosphaerella rubina*, was prevalent at Lafayette. Crown gall (caused by *Bacterium tumefaciens*) rather high up on the stems was found at Lafayette and in Parke County. Leaf curl was found in black varieties at Lafayette, and mosaic was found on both red and black varieties at

[14] Gardner, Max W. and Kendrick, James B. Potato mosaic and leaf roll: Spread and effect on yield. Trans. Ind. Hort. Soc. 1927:158-168. 1928.

Lafayette and by Dietz in Johnson County. In the Lafayette planting mosaic was severe only on the Honeysweet variety of blacks.

Rye. Mains estimated that leaf rust (*Puccinia dispersa*) caused a loss of five per cent, and reported ergot more prevalent than usual.

Salsify. A rather heavy infection of white rust (*Albugo tragopogonis*) occurred in a garden at Lafayette late in the fall.

Sorghum. Rust (*Puccinia purpurea*) was found on sagrain sorghum in Tippecanoe County on October 19. The seed had been obtained in Texas.

Soybean. Mosaic was noted near Lafayette in September. Leaf spot caused by *Septoria glycines* was found in Hendricks and Tippecanoe counties in the fall, and pod lesions caused by the same fungus were also found. The pod and stem blight, caused by *Diaporthe sojae*, was found very prevalent on October 19 in fields of the Manchu variety near Odell. Most of the plants were dead or dying and the relation of the blight fungus to this condition is not known. There was much wrinkling of the seed coat and many darkened or moldy beans.

The purple seed stain caused by *Cercospora* (or *Cercosporina*) *kikuchii* was found in the varieties Manchu, Dunfield, Midwest, Mansoy, and Ito San. It was found in seed samples from 17 counties and in 53 of the 54 samples examined. The percentage of infection was small, varying from 0.1 to 5, but the presence of even a few discolored seeds is very objectionable from the standpoint of the producer of pure seed. In October the disease was found in the field and indefinite darkened areas on the dying pods were found associated with purple lesions on the underlying seeds. The fungus was cultured from the pod tissues. Much, but not all, of the seed infection appears to emanate from the hilum.

Spinach. Mosaic was noted in Marion County in April and near Lafayette in November.

Strawberry. Leaf spot caused by *Mycosphaerella fragariae* and leaf blotch, caused by *Diplocarpon earliana*, were noted near Lafayette late in June, the latter being more serious in the Sample variety than in the Premier variety. Petiole and peduncle lesions of leaf blotch were very serious in their effects. Dietz reported mosaic, or yellows, serious in Clinton County in June and it was also reported from Miami County in May.

Sunflower. Rust (*Puccinia helianthi*) was found rather prevalent on the older leaves in a field of sunflowers in Hancock County on August 15.

Sweet Potato. Black rot caused by (*Ceratostomella fimbriatum*) stem lesions were found killing slips in Knox County on June 6. Gregory reported serious losses from this disease in Gibson County in October, and also found considerable Fusarium wilt. He found surface dry rot, caused by *Fusarium oxysporum*, in Vigo County in October.

Swiss Chard. Leaf spot, caused by *Cercospora beticola*, was found near Lafayette in November.

Tomato. Septoria leaf spot was the worst disease in the canning crop and unquestionable evidence of its introduction on southern grown plants was obtained. In an experimental field at Pendleton set with plants from Texas, badly diseased plants were found scattered through the field on July 22. The main shoot of each of these plants had usually been killed by large chalky white stem lesions and had been replaced by laterals (fig. 5, A). The infection on these plants was of long standing and other evidence also indicated that these plants had been diseased when they were set out. From these plants as centers considerable spread of infection had occurred and the field was soon generally diseased. A survey revealed a similar severity of Septoria leaf spot in all the localities where plants from the same source had been used, while in other near-by localities the disease was of much less importance.

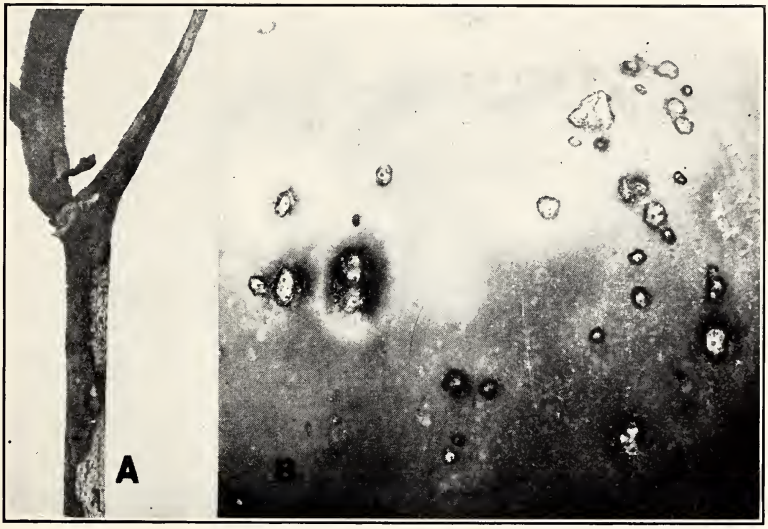

Fig. 5—A. Stem of southern-grown tomato plant showing main shoot (right hand branch at the fork) killed by Septoria infection and being replaced by a lateral shoot. B. Lesions of *Septoria lycopersici* on tomato fruit (enlarged).

The first instance of Septoria infection of the fruit to come to our notice was found on a few plants in one area in this field on September 10 by L. C. Cochran. The lesions were 2 to 3 mm. in diameter, shallow and irregularly circular, with a black border and a white center bearing black pycnidia (fig. 5, B). These pycnidia contained typical Septoria spores. The fungus was isolated and its pathogenicity to young tomato plants was proved by inoculation tests in the greenhouse.

Early blight, caused by *Alternaria solani*, was found by Kendrick on June 1 on plants shipped from Arkansas and heeled-in to await proper weather and soil conditions for planting. The disease was also noted on occasional plants in a greenhouse near Indianapolis on June 28. In an experimental field in Orange County, early blight was first noticed on

July 20 and in September this disease, along with Septoria leaf spot, caused bad defoliation. In a field near Marion visited on August 2 there were numerous cases of early blight collar rot which had resulted in a stunting and rosetting of the plants. Very slight foliage infection and one collar rot case was found in canning crop fields near Acton, Marion County, on August 15. Much stem-end rot, due probably to this fungus, was found in the experimental field in Orange County in September, and an abundance of this rot was noted in the loads of tomatoes being received at the canning factory at Pendleton. The smaller early blight fruit lesions which occur rather commonly late in the season were also abundant.

Because of the cool weather, Fusarium wilt was of very little importance. In greenhouses, a few cases were noted on May 16 and much was noted in the Bonny Best variety on June 28, but none in the Marglobe variety. A few cases were noted in the experimental field near Pendleton on July 22, but the disease never became serious. In a field at Kempton where the plants were inoculated at planting time by placing straw bearing the fungus in pure culture about the roots, no conspicuous cases occurred and only a few were detected by cutting the stems.

In a survey of Indianapolis greenhouses made April 18, when the tomato plants were one to two feet high, much mosaic was found, especially where aphids had been present. The impression was obtained that the inception of mosaic was favored by the presence of weeds and various ornamental plants such as geraniums to harbor aphids, by faulty fumigation, and by unnecessary handling of the tomato plants in tying them up, when the plants, crowded by lettuce, have grown too tall and spindling. The greenhouses were inspected again on May 16 and mosaic was found much more prevalent, as were also the aphids. By June 28 there was practically a 100 per cent infection of mosaic in the greenhouses. The canning crop fields abut Acton and Marion were surprisingly free from mosaic in August while abundant mosaic of early inception was found in fields at Kempton, Pendleton, and Greenfield. There was evidence of the disease being introduced with the Texas plants. A few plants affected with streak or double-virus mosaic were found in the experimental field at Pendleton on August 15 and Gregory found streak in a mosaic crop in a greenhouse at Vincennes in May restricted to the vicinity of two volunteer potato plants.

Leaf mold (*Cladosporium fulvum*) was not found in the greenhouses until June 28 when it had become destructive. Gregory found it a limiting factor in many houses. Bacterial spot, caused by *Bacterium vesicatorium*, was found sparingly in the fruit being unloaded at the factory in Pendleton, and anthracnose, caused by *Gloeosporium phomoides*, was prevalent in certain loads. Kendrick found stem rot caused by *Sclerotium rolfsii* on June 1 in transplants grown in Arkansas.

Blossom-end rot was reported severe in a greenhouse in Gibson County in May. The stem-end yellowing, which is very objectionable to the canners, was due to the prevention of red pigment formation by the hot sun because the normal red color was often present in the narrow strip shaded by the pedicel. Besides this type of sun injury, actual

sunscald also occurred rather commonly during the very hot weather in September. Cyanide injury, characterized by crinkling and downward curling of the leaves and small white papery lesions, was found in greenhouses on the leaves that were young when the fumigation occurred. A. H. Watson found definite and distinct potash hunger symptoms on the older leaves on the dark loam soils of north central Indiana.

Turnip. Powdery mildew (*Erysiphe polygoni*), gray leaf spot caused by *Alternaria herculea*, and mosaic were found in a garden near Lafayette in November.

Wheat. Stem rust (*Puccinia graminis*) was too late to cause loss according to Leer, although he found barberry infection as early as May 1. Leaf rust (*P. triticina*) was very severe and caused a loss estimated by Mains at more than 10 per cent. Leaf rust was found abundant in a field in Jackson County as early as May 4. Loose smut (*Ustilago tritici*) was of usual prevalence.

There was a very serious epiphytotic of bunt (*Tilletia laevis*) which caused widespread concern among the growers and a very considerable loss, not only in yield, but in quality. Numerous complaints and inquiries were received. Leer, who saw wheat fields in all parts of the state, reported this disease fully twice as destructive as he had ever seen before. In a survey of seven farms in Clinton County, Cochran found that the percentage of smut balls in the grain varied from 0.5 to 7.5 and that the grain from three of these farms was docked 2 to 5 cents per bushel, while the grain containing 7.5 per cent of smut balls was unsalable. He estimated that about half of the farmers in that section failed to treat the seed for this crop.

Scab, caused by *Gibberella saubinetii*, was more serious than it has been since 1919. Septoria leaf spot was very prevalent early in the season and Septoria glume blotch was noted by Mains. Anthracnose, caused by *Colletotrichum cereale*, was found by Beeson in Jackson County early in June, and Mains found this disease very serious. Mains also observed Helminthosporium blight, powdery mildew, and ergot.

Trees. Chestnut blight, caused by *Endothia parasitica*, was found by Dietz in a forest planting in Posey County made in 1908, and in forest plantings in Clark and Wayne counties by Prof. B. N. Prentice. It has been possible to explain the previously recorded occurrences of this disease in Indiana by nursery stock importation but Prentice states that the Wayne County planting, above mentioned, was from seed.

A rust (*Gymnosporangium germinale*) on hawthorn fruits was sent in from Marion County. Anthracnose of shagbark hickory, caused by *Gnomonia caryae*, was noted in White County, on October 8, as was also powdery mildew (*Microsphaera alni*) on hornbean, ironwood, white oak, and black oak. Powdery mildew (*Uncinula circinata*) was noted on silver maple and black maple in October. In June, anthracnose, caused by *Gnomonia veneta*, was very prevalent on white oak, but black oak seemed to be free from it. Leaf blister, caused by *Taphrina coerulescens*, was prevalent on black oak.

Canker, caused by *Dothichiza populea*, occurred on Lombardy poplars, and leaf spot, caused by *Marssonia populi*, was found on nursery stock in Marion County. Leaf spot of red bud, caused by *Cercospora chionea*, was prevalent. Powdery mildew (*Microsphaera alni*) was common on the leaves of young sycamore trees in October in White County. Anthracnose of sycamore, caused by *Gnomonia veneta*, was extremely serious in the spring, owing to the rains, and completely defoliated older trees as much by its attack on the twigs as on the leaves. Younger trees did not suffer so badly and made a quicker recovery.

Ornamentals. Aster yellows was not as prevalent as usual. Dietz found bacterial spot of carnation, caused by *Bacterium woodsii*. A mosaic disease of coneflower was noted. Powdery mildew (*Erysiphe cichoracearum*) on dahlia was sent in from Jefferson County. Bacterial spot of delphinium, caused by *Bacterium delphinii*, was found at Lafayette, as was also the gladiolus rot caused by *Penicillium gladioli*. The hollyhock leaf spot caused by *Cercospora althaeina* was noted. Bacterial soft rot and dry rot, caused by *Sclerotium delphinii*, were the most serious iris diseases. Dietz reported leaf spot, caused by *Didymellina iridis*, to be especially abundant. Bacterial spot of the kudzu vine, caused by *Bacterium puerariae*, was found in June. A Botrytis leaf spot of Madonna lily was found in a greenhouse. A Colletotrichum leaf spot of pansy occurred in Tipton County in October.

A serious outbreak of Phytophthora blight of peonies occurred near Vincennes late in April. Pierce inspected the plantation and reported the disease worst on the varieties, Felix Crouse and Festiva Maxima. The fungus causing this disease was found by Cooper and Porter[15] to be an undescribed species which they named *Phytophthora paeoniae*. Dietz reported black spot of rose, caused by *Diplocarpon rosae*, very serious in greenhouses and also out-of-doors. He also reported powdery mildew (*Sphaerotheca pannosa*) worst on Dorothy Perkins and Crimson Rambler out-of-doors and on Premier and Double White Killarney in greenhouses. A fasciation of sweet peas occurred in two greenhouses, and Gregory found root rot, caused by *Thielavia basicola*, in a greenhouse in Floyd County. Damping-off of oriental poppy plants, caused by Rhizoctonia, occurred in a greenhouse at Lafayette. Mains[16] has reported a number of other diseases.

Weeds and Wild Plants. *Peronospora potentillae* and *Ramularia arvensis* were found on cinquefoil, *Cercospora physalidis* on *Physalis pubescens*, *Plasmopara halstedii* on Helianthus sp., *Cercospora monoica* on hog peanut, *Sphaerotheca humuli* var. *fuliginea* on *Lactuca villosa*, *Plasmopara viticola* on wild grape, and *Septoria polygonorum* on smartweed. Additional records may be found in Van Hook's article (l. c.).

[15] Cooper, Delmer C. and Porter, C. L. Phytophthora blight of peony. Phytopathology 18:881-899. 1928.

[16] Mains, E. B. Plant diseases in a home garden. Proc. Ind. Acad. Sci. 1927:341-353. 1928.

SUMMARY.

The diseases of outstanding importance were as follows: apple scab and blotch, celery Septoria blight, cherry leaf spot, clover anthracnose, currant and gooseberry anthracnose, crown rust of oats, onion neck rots, peach bacterial spot and brown rot, raspberry anthracnose, sweet potato black rot, tomato Septoria leaf spot and early blight, wheat leaf rust and bunt, sycamore and oak anthracnose, and Phytophthora blight of peonies.

The diseases or parasitic organisms not previously reported for the state, at least in this series, include: alfalfa stem blight caused by *Pseudomonas medicaginis; Nectria cinnabarina* on apricot; bean angular leaf spot caused by *Isariopsis griseola; Alternaria brassicae* on Brussels sprouts; leaf spot on Chinese cabbage caused by *Alternaria herculea;* bacterial spot of carnation; coneflower mosaic; corn foot rot caused by *Ophiobolus heterostrophus;* bacterial spot of delphinium; gladiolus corm rot caused by *Penicillium gladioli; Bacterium puerariae* on kudzu vine; onion mycelial neck rot caused by *Botrytis byssoidea,* small sclerotial neck rot caused by *Botrytis squamosa,* and Fusarium pink stain; pear brown bark spot or measles; sorghum rust (*Puccinia purpurea*); Thielavia root rot of sweet peas; tomato stem rot caused by *Sclerotium rolfsii;* and gray leaf spot of turnip caused by *Alternaria herculea.*

Other observations of interest were the occurrence of Phytophthora rot on young green apples, a fall outbreak of apple pink rot in Grimes probably following surface bitter pit, *Isariopsis griseola* on bean pods, resistance of London Market currant to anthracnose, sunscald of onions, resistance of Plum Farmer black raspberry to anthracnose, importation of tomato Septoria on southern grown plants, and Septoria lesions on tomato fruit.

STUDIES OF TOMATO QUALITY, IV.[1] VARIABILITY IN QUALITY AND FOOD VALUE OF TOMATOES.

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Fruits are used in the daily diet of practically all American people because of their health-insuring properties, such as vitamines, organic acids and minerals. Since fruits contain from 85 to 95 per cent water, a vary small fluctation in the percentage of water will greatly vary the amount of dry matter and consequently caloric value of the fruit.

Investigations were begun in 1925 to study the quality of tomato fruits, methods of measuring quality, and methods of improving the quality of our present varieties. In order to know the possible variability in composition, analyses were made of 38 individual fruits picked from eight plants. In collecting samples from different experiments for analysis, it was desirable to have some information as to the variability of fruits from the same plant and from different plants throughout the season.

Methods of Analysis. Fruits were collected from eight adjacent plants of the Indiana Baltimore variety which were surrounded on all sides by tomato plants. Boiling alcohol was used to kill and preserve the tomatoes for analysis. This action was hastened by cutting the whole fruits into thin pieces before they were dropped into boiling alcohol. The fruits were preserved in approximately 50 per cent alcohol. Calcium carbonate was not added to the samples, because there seemed to be little or no sucrose present. After a storage of three months, the alcoholic extract and residue of the samples was obtained in the usual manner (1).

Dry Matter. One-twentieth aliquots of the alcoholic extract and residue were placed in evaporating dishes and reduced almost to dryness on a steam bath. The dishes were transferred to a steam oven containing hydrogen and dried for a period of four hours.

Nitrogen. One-tenth aliquots of the extract and residue were placed in a Kjeldahl flask, evaporated to dryness on a steam bath, and the total nitrogen was determined by the official Kjeldahl-Gunning-Arnold method modified to include nitrates (2).

Acidity. One-tenth aliquots of the alcoholic extract were placed in a beaker which had been previously washed with boiled distilled water. The alcohol was expelled by evaporating on a steam bath with the addition of small amounts of distilled water. A one-fifth aliquot of this sample was diluted with 200cc. of boiled and cooled distilled water and tirated with one-tenth normal sodium hydroxide. Phenolphthalein was used as an indicator. The results are expressed as anhydrous citric acid.

[1] See "Literature Cited."

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

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Reducing Sugars. One-tenth aliquots of the alcoholic extract were evaporated on a water bath with the addition of distilled water until all the alcohol had disappeared. The solution was cleared by means of neutral lead acetate and de-leaded with sodium carbonate. Phenolphthalein was used to indicate when the solution was completely de-leaded. The Munson and Walker conditions were used in reduction. The amount of reduced copper was determined by the Shaffer and Hartman titration method (3).

Fruit Solids. Quality of tomatoes must be confined to compounds and relations between the compounds found in the dry matter or solids of the fruit. The solids contain many desirable characteristics;—(1) the bright red color, (2) the flavor which is due to the sugar and acid ratio as well as the volatile oils and perhaps esters of organic acids, (3) the calories, and (4) vitamines of the tomato.

A tomato with a high percentage of dry matter is very desirable from several standpoints. The fruit is sold either on a weight or volume basis, therefore the percentage of dry matter greatly affects the cost of each unit of food. The characteristic tomato flavors are more concentrated in fruits of low water content. The percentage of dry matter is very important for canning factories purchasing fruit for the manufacture of tomato pulp. Tomatoes are purchased from the farmers on a fresh weight basis, while the pulp is sold for use in soup and with baked beans on a water-free basis or at a definite specific gravity. Evidently the canner is buying his fruit without regard to water content and selling his finished produuct with a stated amount of water in it. Necessarily his margin of profit must be great enough to take care of the shrinkage.

Variability in Composition. Tomatoes are very variable in composition with respect to the percentage of dry matter as well as the organic compounds determined (Table I or II). It was hoped at first that these data could be used to estimate the number of fruits necessary for an adequate sample for chemical analysis. After a frequency graph was prepared from these data, the number of fruits who too limited to make such an analysis of any benefit. The only uniform results which can be observed were the greater acidity of fruits late in the season and consistent differences in composition of fruits ripened on different plants.

Heredity of the Plant and Fruit Composition. Although the number of fruits from each plant is small for statistical analysis, it was thought worth while to determine whether there was a significant difference in organic content of fruits from the different plants. No data are available on this point for tomatoes. Any information on these points should be of great importance in selection work for the improvement of varieties.

The mean for all fruits from each plant was determined by the usual statistical methods. After these mean values had been determined, the plant in every case containing the lowest value was compared with the other plants. This method was followed to insure a uniform method of comparison.

Tomato fruits from these plants according to Tables II, III, IV, and V, differ quite frequently in dry matter and acid content, only rarely in nitrogen, and never in sugar content. As the tables show, the odds in many of these comparisons is very high when one considers that odds of 22 to 1 are usually considered significant. According to these data, selection could not be satisfactorily used to increase the sugar content of fruits. If a sweeter fruit is very desirable the most logical point of attack would be to select fruits of a lower acid content as this will result in a fruit of a sweeter taste. Sugar has a marked effect on the taste of acids. Canners at the present time are in need of a variety of tomatoes of high dry matter content. Although environmental factors very likely affect the dry matter content of tomatoes, the results indicate that selection might be used advantageously to decrease the water content of the fruits.

SUMMARY.

1. Tomato plants produce fruits that are variable in composition, food value, and quality.

2. The small amount of data presented here seems to indicate that heredity of a tomato plant may be partly responsible for the variation in composition.

TABLE I. Variablilty in Composition of Tomatoes of the Same Variety.

	Dry Matter	Nitrogen	Acidity	Reducing Sugars
Maximum Percentage	10.62	5.72	11.63	45.70
Minimun Percentage	6.00	1.74	3.28	32.38
Average Percentage	7.56	2.62	6.76	39.93

TABLE II. A Statistical Analysis of Percentage of Dry Matter in the Fruits From Eight Tomato Plants.

Plant No.	Mean	Probable Error	Comparison based on Plant 2	Difference of Means	P. E. of difference	Odds Significant
2	6.36	.066				
3	7.88	.148	2-3	1.52	.152	in* to 1
4	6.90	.145	2-4	.54	.157	45 to 1
5	6.93	.169	2-5	.57	.179	31 to 1
6	7.95	.338	2-6	1.59	.343	520 to 1
7	9.15	.371	2-7	2.79	.376	427,000 to 1
8	8.62	.229	2-8	2.26	.236	in* to 1
9	7.05	.096	2-9	.69	.113	19,300 to 1

*Odds are at least 65,000,000,000 to 1.

TABLE III. A Statistical Analysis of Percentage of Nitrogen in the Fruits from Eight Tomato Plants.

Plant No.	Mean	Probable Error	Comparison based on Plant 4	Difference of Means	P. E. of difference	Odds significant
2	2.77	.035				
3	3.08	.090	4-2	.40	.067	19,300 to 1
4	2.37	.058	4-3	.71	.106	19,300 to 1
5	2.42	.068	4-5	.05	.089	1 to 1
6	2.57	.099	4-6	.20	.114	3 to 1
7	2.77	.138	4-7	.40	.149	14 to 1
8	2.49	.141	4-8	.12	.149	1 to 1
9	2.50	.118	4-9	.13	.131	1 to 1

TABLE IV. A Statistical Analysis of Percentage of Acidity in the Fruits from Eight Tomato Plants.

Plant No.	Mean	Probable Error	Comparison based on Plant 2	Difference of Means	P. E. of difference	Odds significant
2	5.25	.066				
3	8.75	.064	2-3	3.50	.011	in* to 1
4	5.25	.064	2-4	0.0	.091	0 to 1
5	7.15	.081	2-5	1.90	.104	in* to 1
6	6.35	.063	2-6	1.10	.090	in* to 1
7	8.35	.386	2-7	3.10	.123	in* to 1
8	8.50	.799	2-8	3.25	.253	in* to 1
9	5.50	.380	2-9	.25	.122	5 to 1

*Odds are at least 65,000,000,000 to 1.

TABLE V. A Statistical Analysis of Percentage of Sugar in the Fruits from Eight Tomato Plants.

Plant No.	Mean	Probable Error	Comparison based on Plant 9	Difference of Means	P. E. of difference	Odds significant
2	41.0	1.14	9-2	2.2	1.79	1.4 to 1
3	39.5	1.00	9-3	0.7	1.71	1 to 1
4	42.0	.76	9-4	3.2	1.59	18 to 1
5	39.8	.90	9-5	1.0	1.66	1 to 1
6	39.4	.70	9-6	0.6	1.56	1 to 1
7	39.4	.46	9-7	0.6	1.47	1 to 1
8	41.5	1.00	9-8	2.7	1.71	2.6 to 1
9	38.8	1.39				

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THE ECOLOGY OF TURKEY RUN STATE PARK.

PART I—THE FLOOD PLAIN.

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Sugar Creek, one of the large tributaries of the Wabash River, flows in an east to west direction through Turkey Run State Park. It rises well to the east of Parke County and carries an abundance of water. "Sugar Creek seems to be flowing through a post-glacial channel as far as the mouth of Brush Creek. Its immediate valley is usually narrow and often hemmed in by cliffs of Mansfield sandstone. Its principal tributaries from the north are Brush Creek and Sugar Mill Creek. The latter valley is somewhat of the type of Sugar Creek; the former is thought to have been possibly the pre-glacial channel of Sugar Creek, and its banks show little but glacial deposits of sand, clay, and gravel. From the south side the principal tributary is Roaring Creek, which in the lower part of its course, winds through a narrow, rocky ravine. At Turkey Run many of the small tributaries are, over the lower part of their courses, inclosed in rocky gorges with perpendicular or overhanging walls."[1]

Sugar Creek and its tributaries, flowing through glacial deposits, carry small boulders, pebbles, and gravel, besides silt and clay. The coarser materials are the tools the streams use in cutting their beds wider and deeper in the massive sandstone. Only a part of the sand and silt is deposited on the lowlands, greater quantities being carried long distances before being deposited. On reaching the Wabash, Sugar Creek carries a great load of sand.

The current of Sugar Creek is swift; eddies and rapids are found in many places. The level of the water varies; the difference between lowest and highest in one year amounting to as much as 20 feet. Seasonal variations have been quite marked during the four year period covered by this study. High water level and the accompanying flooding of the lowlands characterized the springs of 1925, 1926, and 1927; the lowest recorded level for the period between April 27 and May 6 occurred in 1928. At normal rise the gentle slopes along the south bank of Sugar Creek are flooded for a distance of 75 feet or more back from the mean water shore line.

The banks of Sugar Creek are of the depositing-and-eroding type. On both banks are evidences of erosion alternating with deposition. There are also good illustrations of the work that is due to the oscillating movements of the stream. Opposite a gravel bar or levee on one bank is a strip where erosion is going on. East of the Narrows near

[1] Harold Orahood, Soil Survey of Parke County. 38th Ann. Rept. Ind. Dept. of Geol. and Nat. Resources. 1903.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

the mouth of Brush Creek, the rocky cliffs disappear and low fertile fields border the creek. Near the mouth of Brush Creek, a xerophytic upland forest of red cedar, and white, black and chestnut oaks adjoins the remnant of a flood plain whose giant sycamores and young elms are being rapidly undermined by the swift current and being toppled into the stream. A small number of *Populus deltoides*[1] are found on both banks of Brush Creek at its mouth. About 100 feet southwest of the mouth of Brush Creek the rock outcrops begin on the right bank of Sugar Creek and continue for some distance beyond the Narrows. On the left bank the rock cliffs start near the covered bridge. Thus the creek is suddenly hemmed in at the Narrows between precipitous and resistant sandstone cliffs. These cliffs continue along both banks but a short distance. So the building up of the flood plain continues.

Three types of flood plains are found in Turkey Run State Park: (1) the gravel bar, the most common type, (2) the sand bar, and (3) the alluvial plain. The climax is the same in all three.

1. The Gravel Bar. The gravel bar is made up mostly of gravel, pebbles, and small cobblestones. The cobblestones are rolled or pushed along the stream bed and are deposited when an obstruction such as a fallen tree or a rise in the bed of the stream is met. Anything that serves to check the current causes deposition. The stones and gravel being the heaviest material carried, are dropped farther from shore than the sand or silt. Thus off-shore bars or islands are formed. These form an obstacle in the creek and further deposition results. The islands or bars may become joined to the mainland or they may, by a deflection of the current, be eroded on the side nearest the shore and not make contact with the mainland. In the latter case they may continue as islands or may in time be completely eroded away. In the former case there will be developed on them a vegetation which will begin with the amphibians and xerophytic summer annuals and proceed from the willow stage to the flood plain climax forest.

2. The Sand Bar. The sand bar is less porous than the gravel bar, is a less xerophytic habitat, and begins nearer to the mainland. Summer annuals and perennials are succeeded in a relatively short time by the willows and sycamores.

3. The Alluvial Plain. The alluvial plain is built up at the water's edge. It is formed of deposits of fine silt. In time of flood, the current in the main channel is swift; but as soon as the water spreads beyond its channel, its velocity is checked because its depth becomes less, and it promptly abandons much of its load. During the period of overflow, the edges of the channel current are checked by the slower moving flood-plain water, and this causes further deposition on the banks of the channel. Repeated deposition in this position gives rise to levees. Natural levees have been built up on the north bank of Sugar Creek, southwest of the Ice Box. The alluvial plain is usually moist through the greater part of the spring and summer. A rich hydro-mesophytic and mesophytic vegetation develops. After the spring freshlets have

[1] All names are from Gray's Manual, 7th ed.

gone an algal vegetation is found on these flats. In late summer *Polygonum pennsylvanicum*, *P. lapathifolium*, *Rumex verticillatus*, and *Asclepias incarnata* are abundant, while *Bidens cernua*, *Menthes virginianum*, and *Cicuta maculata* occur in scattering patches.

The flood plains of Turkey Run offer a very diagrammatic study. The zonation is not always well marked nor are the stages always well represented. The following stages in the development of the flood plain are found: (1) Aquatics, (2) Dianthera stage, (3) Willows, (4) Sycamores, (2, 3, 4, constitute the lower flood plain), (5) Elm and Ash (middle flood plain), and (6) Climax Flood Plain Forest (upper flood plain).

1. Aquatics. In the shallow protected places and on the mud flats in late summer are found the algae. This stage is not well represented. Of the emergent aquatics, only one patch of *Sagittaria latifolia* was found in August, 1927 near Goose Rock.

2. Dianthera stage. This zone is submerged during most of the spring and partially or entirely emergent in late summer. *Dianthera americana* (Water willow) is the dominating species in this zone on the gravel and sand bars. *Rumex verticillatus*, *Polygonum pennsylvanicum* and *P. lapathifolium* dominate the alluvial plain. These plants slow up the current and cause deposition of part or all the water's load. They also make difficult the removal of the materials already deposited. The building up of the bar or levee continues and the layer of finer materials becomes deeper until finally the conditions for the next stage to become started prevail. *Ambrosia trifida* and *Xanthium canadense* are the two most common herbs of the late summer.

3. Willow stage. The first tree stage is characterized by *Salix nigra* (black willow), *Acer saccharinum* (white maple) and *Salix longifolia* (sandbar willow). *Acer negundo* is only sparsely represented in this zone along Sugar Creek but it is the dominating species of this zone along Sugar Mill Creek in the new tract to the northwest. Among the herbs these are found: *Radicula palustris* (marsh cress), *Rumex crispus* (yellow dock), *Ranunculus septentrionalis* (early buttercup), *R. abortivus* (aborted buttercup), *Verbena urticaefolia* (white vervain), *Ambrosia trifida* (great ragweed).

4. Sycamore stage. The sycamore (*Platanus occidentalis*) comes in after the willows. It is the tree that gives the characteristic aspect to the scenery along the streams in this region. It is able to endure considerable flooding and partial burying by sand or silt. Its power of sending out adventitious roots is remarkable. The sycamores are among the largest trees found in the park, the largest sycamore measuring over 22 feet in circumference. The many large ones on the south bank of Sugar Creek are the remnants of this stage of the flood plain. The herbaceous vegetation of the preceding stage carry over into this stage. The new species are *Solidago serotina* and *Plantago rugelii*.

5. Elm and Ash stage. As the flood plain builds up and becomes dry enough to permit the germination and development of a mesophytic vegetation, the willows and sycamores are replaced by elms and ash. *Ulmus americana*, *U. racemosa*, and *Fraxinus americana* are the domi-

nating trees. *Ulmus fulva* and *Sambucus canadensis* are common. The herbaceous plants include: *Steironema ciliatum* (fringed loosestrife), *Ranunculus septentrionalis* (early buttercup), *R. abortivus* (aborted buttercup), *Rudbeckia laciniata* (wild goldenglow), *Lysimachia Nummularia* (moneywort), *Bidens vulgata* (begger-ticks), *Helianthus tuberosa* (Jerusalem artichoke), *Rumex crispus* (yellow dock,) *Oenothera biennis* (evening primrose), *oxalis corniculata* (lady's sorrel).

6. Climax Flood Plain Forest. A rich mesophytic flood plain forest succeeds the elms and ash. There is no flooding of this forest except at periods of high water level, the period of flooding being relatively short. Walnut and butternut (*Juglans nigra* and *J. cinerea*), Ohio buckeye (*Aesculus glabra*), water or blue beech (*Carpinus caroliniana*), black sugar maple (*Acer saccharum* var. *nigrum*), hackberry (*Celtis occidentalis*), tulip (*Liriodendron tulipifera*), redbud (*Cercis canadensis*), Kentucky coffee tree (*Gymnocladus canadensis*), mulberry (*Morus rubra*), pawpaw (*Asimina triloba*), *Fraxinus amcricana*, basswood (*Tilia americana*), slippery and cork elms (*Ulmus fulva* and *U. racemosa*) are the tree members of this association. The members whose chief range is mainly southward are: the coffee tree, pawpaw, hackberry, redbud, mulberry, and tulip or yellow poplar.

Lianas are conspicuous in this rich flood plain forest. Virginia creeper (*Psedera quinquefolia*), greenbrier (*Smilax hispida*), frost and river-bank grape (*Vitis cordifolia* and *V. vulpina*), moonseed (*Menispermum canadense*), and poison ivy (*Rhus Toxicodendron*) climb over the trees and hang in festoons from the branches.

The undergrowth is particularly beautiful and luxuriant due to the fertility of the soil and conditions of shade and moisture. Among the shrubs are: *Benzoin aestivale* (spicebush), *Evonymous atropurpureus* (Wahoo or burning bush), *Cornus alternifolia* (alternate leaved dogwood), *Cornus Amomum* (silky dogwood), *Dirca palustris* (leatherwood), *Staphylea trifolia* (American bladdernut), *Viburnum Lantago* (nanny berry), *V. prunifolium* (black haw), *Xanthoxylum americanum* (prickly ash), *Cartaegus punctata* (punctate haw), *Ribes Cynosbati* (prickly gooseberry), *Clematis virginiana* (virgin's-bower).

The herbaceous vegetation is dominantly vernal, the shade being too dense for a typically aestival flora. The list of herbs includes many that are also found in the climax forest of the region. The following spring herbs are prominent in this association: [1]**Mertensia virginica* (Virginia cowslip or bluebells), **Claytonia virginica* (spring beauty), **Erythronium americanum* (yellow adder's tongue), **E. algidum* (white adder's tongue), **Phlox divaricata* (blue phlox), **Trillium recurvatum* (wake-robin), **Polemonium reptans* (Jacob's ladder), **Hydrophyllum appendiculatum* (water leaf), **Viola cucullata* (blue violet), **Arisaema triphyllum* (Jack-in-the-pulpit), *A. Dracontium* (green dragon), *Ispoyrum biternatum* (false rue anemone), *Caltha palustris* (marsh marigold), *Dicentra cucullaria* (Dutchman's breeches), *D. canadensis* (squirrel corn), *Palygonatum biflorum* (small Solomon's seal), *P. commutatum* (great Solomon's seal), **Cardamine Douglasii* (spring cress), *C. bulbosa*

[1] Indicates dominant species.

(spring cress), *Hydrophyllum virginianum* (waterleaf), *H. macrophyllum* (waterleaf), *Osmorhiza Claytoni* (sweet cicely), *O. longistylis* (sweet cicely), *Silene virginica* (fire pink), *S. stellata* (starry campion), *Viola pedata* (blue bird's foot violet), *V. sooria* (blue violet), *V. striata* (pale blue violet), *Asarum canadense* (wild ginger), *Scutellaria lateriflora* (skullcap), *Allium tricoccum* (wild leek), *A. canadense* (wild onion), *Sanguinaria canadensis* (bloodroot), *Oxalis corniculata* (yellow wood sorrel).

Other characteristic herbs are: **Urtica gracilis* (nettle), *Pilea pumila* (clearweed), *Laportea canadensis* (wood nettle), *Elymus striatus* (slender wild rye), *Sisyrinchium albidum* (blue-eyed grass), *Smilacina stellata* (false Solomon's seal), *Acalyphy virginica* (mercury weed), *Achillea millefolium* (yarrow), *Actimeris alternifolia* (yellow iron weed), *Agastache nepetoides* (giant hyssop), *Agrimonia gryposepala* (agrimony), *Boehemeria cylindrica* (false nettle), *Cacalia atriplicifolia* (Indian plantain), *Camasia esculenta* (wild hyacinth, *Camoanula americana* (tall bellflower), *Carex grisea* (gray sedge), *Crytotaenia canadensis* (honewort), *Daucus carota* (wild carrot), *Erigeron annuus* (white top), *Eupatorium purpureum* (Joe Pye weed), *Evonymous obovatus* (trailing strawberry), *Galiuum Aparine*, *Geranium maculatum* (wild geranium), *Geum canadense* (white avens), **Lobelia syphilitica* (great lobelia), *Impatiens pallida* (pale jewel weed), *I. biflora* (spotted Jewel weed), *Lysimachi Nummularia* (moneywort), *Mitchella repens* (partridge berry), *Physostegia virginiana* (false dragon head), *Polygonum virginianum* (Virginia knotweed), *Sisyrinchium albidum* (blue-eyed grass), *Verbena urticaefolia* (white vervain).

A luxurious and extensive patch of *Monarda fistulosa* was found not far from the Swinging Bridge on the mature flood plain. It is more typical of dry soils.

In many places along both banks of Sugar Creek are evidences of retrogression in connection with the flood plain climax forest. The creek after building up for a considerable time begins to destroy what it has built. This may begin at any stage in the flood plain development; more frequently it destroys the climax forest. On the left bank west of Goose Rock the huge sycamores are being undermined by the stream and gradually, after a severe struggle, they are toppled into the water. Here they form an obstruction in the path of the current and in some instances have been the means of saving some of the other trees from a similar fate by causing deposition to be re-initiated.

On the north bank the climax forest is being rapidly destroyed in a few places.

SUMMARY.

1. Sugar Creek seems to be flowing through a post-glacial channel. It carries much glacial drift consisting of small boulders and pebbles. These are deposited, forming gravel bars.

2. Only a small portion of the load of sand is deposited on the banks.

3. The banks of Sugar Creek are of the eroding-and-depositing type.

4. Three types of flood plain are developed; the climax is the same in all three.

5. Six stages or associations are shown, aquatic, dianthera, willow, sycamore, elm and ash, and climax flood plain forest.

6. The majority of the trees of the flood plain climax are southern as to range.

7. The climax flood plain forest is in many instances a temporary climax due to retrogression caused by a change from depositional to erosional phase.

This study was begun in the spring of 1925 when I visited Turkey Run State Park for the first time with a class conducted by Dr. Henry C. Cowles of the University of Chicago. Since then I spent part of each spring and summer up to and including 1928. On a special week-end trip in November, 1925, a study of the mosses was begun under Dr. Cowles' direction.

The results of the study are divided as follows: I. The Flood Plain. II. The Canyons. III. The Upland Forests. Parts II and III will appear in later issues of the Proceedings of the Indiana Academy. A list of the mosses and liverworts is to be published soon in the Bryologist.

I wish to express my thanks to Dr. Henry C. Cowles of the University of Chicago for his kindly help and inspiration during the progress of the investigation. I desire also to thank Mr. Elim, Superintendent of Turkey Run State Park, Sidney R. Esten, Otto Behrens and Fred Test, Nature Guides, for assistance given during the summers of 1927 and 1928.

MILEAGE OBTAINED FROM SOME COMMERCIAL GASOLINES.

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Gasoline refiners in 1905 were getting less than four gallons of gasoline from a barrel of petroleum. Due to increased consumption, in 1923 they were getting 13 gallons by cutting deeper into the crude oil. This would have been inadequate had they not also resorted to cracking the heavy petroleum oils. Of course this made a less volatile gasoline and more difficult of use in automobiles, but by blending it with the more volatile casinghead gas, obtained from natural gas, they were able to make a very satisfactory product, giving probably a little more mileage than the old straight run gasoline. Today over 50 per cent of petroleum is turned into gasoline.

So the supply of gas has been able to keep pace with the growing demands, and to do so without working hardships on most makes of cars. But these necessary deviations from the old straight distillation process is putting a greater and greater variety of gasolines on the market. Then, due to the fact that some makes of cars have been slow to adopt self starters and other devices which would enable them to use the less volatile gasolines, the refiners were obliged to prepare still another more volatile type of gas known as the high test or aviation gas. This gas is indispensable for airplanes. It makes a good gas for use in winter and cold climates and in cars which start with difficulty when the motors are cold; but the more there is of the low boiling fraction present in a gasoline the less the mileage and the higher the cost of the gasoline. The distillation ranges of gasolines on the market today show a tendency toward a single product for summer and winter use; and are leaving it to the manufacturers to adapt the cars to a standard gasoline for all seasons.

We seem destined to have a special gasoline for the high compression engines, a gas that will stand greater pressure without knocking. The problem has been partially solved by the addition of certain anti-knock substances to the ordinary gasoline.

Then the keen effort to conserve our petroleum has drawn to some extent alcohol and the benzol hydrocarbons into the preparation of gasolines. What has been said thus far in way of introduction is not for the purpose of describing these gases or finding fault with the number of them, but merely to call your attention to the fact that when you drive up to a station to fill your gasoline tank you have a bewildering variety from which to choose, and there seems to be a growing tendency to have at least four gasoline companies represented at each cross street; each dispensing at least two grades of gas, superior in mileage and "pep" to the types sold on the other three corners.

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In the absence of technical knowledge or training and of any gasoline recommendations from the manufacturer of the car, how is the average automobile driver to know which gas will give the best service? Aside from the matter of starting a cold, "lazy" motor, the most vital question for the average low pressure engine is that of the mileage obtainable from the various gasolines by their actual use on the road.

Every autoist has determined the mileage of some gasoline by using it on a trip and dividing the speedometer reading by the number of gallons of gasoline purchased. Results thus obtained are practically worthless for comparison of gasolines, since they do not take into account various factors which influence the mileage, such as the wind, condition and kind of roads, load carried, traffic congestion, tire inflation, speed of travel, and actual quantities of gasoline received at filling stations. There are enough variables involved in running an automobile that any mileage results obtained by disregarding them must be looked upon with a bit of suspicion.

So this paper is a report of an investigation undertaken with the intention of taking these variables into account just as fully as the circumstances would permit. But at best, the results are not strictly quantitative in character and the order of the mileage might have been somewhat different had some other make of car been used. The report is given, however, with the hope that the method at least may have some value.

A two-passenger Buick coupe, weighing 3,215 pounds, was used in the tests. The car had been run only about 5,000 miles and was in excellent running condition. A temporary gas tank holding slightly more than a gallon was mounted above and to the side of the carburetor. A T-connection was placed in the main fuel line at the point where it enters the carburetor. Through its side arm the gasoline from the temporary tank was admitted to the main fuel line. Valves were placed in each line so that the gasoline might be fed to the carburetor from either tank as desired.

A run with a given gasoline was made by placing a gallon of it in the temporary tank. A narrow neck bottle was used to measure the gasoline. It was calibrated to deliver a gallon at 25° C. The calibration mark was on the narrow neck. A second bottle of the gasoline was taken along for the return trip. The runs were made on a wide concrete road on which traffic was light. Nearly all the route is level. The runs were all made when the road was dry, and they were usually made early in the morning when the traffic was lightest. The car was driven to the starting point just outside the city. By this initial run and by means of the heat regulator the engine was warmed up to 130°, its normal temperature. This temperature was maintained as nearly as possible throughout the run. At the starting point the gasoline was shut off from the regular tank and the car run "idle" until the gas in the pipe and carburetor was used up. The valve in the temporary line was now opened, the trip speedometer set at 0 miles, and the car started and run as nearly as possible at a speed of 25 miles until the gallon

of gas was used up. The speedometer reading gave the mileage for the trip out.

The valves in the two gas lines were reversed. The car was run a few feet further, turned, and driven back to the spot where the run had ended. The extra gallon of gasoline was put into the temporary tank, and the same procedure followed in making the return trip as on the outward trip. The run was made both ways in an attempt to eliminate the effect of any wind which might be assisting or retarding the speed; and to correct for any difference in elevation of the starting and ending points. The average of the two mileages was taken as the mileage for that particular gasoline.

The tires were each time inflated to 38 pounds pressure, and the carburetor properly adjusted for the gasoline. The same load was carried in the car, and the windows lowered the same distance to make the resistance of the air uniform in all the runs. In none of the runs was it necessary to stop the car or to change the speed more than two or three miles, and then only for a very short time. It is generally thought by experts that a car will give the best mileage when running at a speed of 20 miles. If this is the speed of maximum efficiency, then running either faster or slower decreases the mileage. But at a 25 mile speed deviations above and below tend to correct each other. While this speed may have cut down the mileage slightly, the comparative results were made more accurate. The relation of speed and mileage is shown in one of the runs with Indian common gasoline which was made at 40 miles speed. This cut the mileage from 17.83 to 16.

The results obtained by using 24 of the more common gasolines, purchased at the regular filling stations, are tabulated in the table on the following page.

It is very easy to draw false conclusions from these data. The relative commercial values of these gasolines is not shown by these mileages for they are not all competing solely on the mileage basis. There is no very sure standard for rating them when such qualities are considered as freedom from knocking, ease of starting, carbonizing the cylinder, etc. But for the particular car used in these tests, and probably for most cars, these figures represent the relative number of miles per gallon which can be obtained from these different gasolines.

The distillation range of each gasoline was determined and appears in the table. This was done to see if the mileage might not be a function of the position and shape of the distillation curve. In general the higher the end point the greater the mileage, unless it has also a large volatile fraction. This is due to the fact that the larger molecules burn longer and deliver power during the entire stroke of the piston. But a few of the curves obtained for these gasolines need further study before any definite statements can be made on the above question.

Table Showing Mileage and Distillation Range of 24 Gasolines Marketed in Terre Haute.

SAMPLE	MILES			Tire Pressure	Speed in Miles	Barometer	Specific Gravity	Cost per Gallon	Cost per 1000 Miles	DISTILLATION RANGE FAH.°													
	Out	In	Aver.							1st Drop	10	20	30	40	50	60	70	80	90	End Point	Recovery	Residue	Dist. Loss
Culley—Common	16.9	16.15	16.53	38	25	747	720	18	10.88	93	140	174	203	232	259	279	313	347	388	433	97	1.7	1.3
Culley—H. T	17.3	17.9	17.6	38	25	750	740	21	11.93	109	165	187	199	214	230	255	291	329	374	421	97.5	1.6	.9
Red Crown	17.2	16.65	16.92	38	25	750	740	18	10.64	111	167	208	230	255	279	300	324	347	379	415	97.5	1.7	.8
Solite	16.7	16.3	16.5	38	25	748	715	21	12.72	100	147	179	207	226	244	256	280	302	334	392	97.5	1.5	1
Diamond—Common	17.15	18	17.58	38	25	748	740	18	10.24	106	167	203	230	261	279	300	325	356	390	448	98	1.7	.3
Diamond—H. T	15.95	17.95	16.95	38	25	750	735	21	12.39	106	169	216	248	273	304	329	347	374	406	455	97.5	1.6	.9
Linco—Common	17.1	18.51	17.8	38	25	750	735	18	10.11	104	158	196	223	248	273	297	322	349	381	421	97	1.7	1.3
Linco—H. T	15.76	16.9	16.33	38	25	750	715	21	12.86	100	144	171	192	212	228	243	261	291	329	383	97	1.5	1.5
SinClair—Common	17.2	18	17.6	38	25	757	735	18	10.23	97	144	190	228	259	288	315	345	370	399	424	97.5	1.2	1.3
SinClair—H. T	17.7	17.85	17.77	38	25	750	750	21	11.81	111	169	207	232	257	279	300	331	365	401	423	97	1.4	1.6
Producers—Common	16.75	18.45	17.6	38	25	751	735	17	9.66	109	169	207	228	250	275	300	331	358	394	432	97.5	1.6	.9
Producers—H. T	16	16.1	16.05	38	25	750	685	20	12.46	100	126	136	147	156	169	179	189	208	235	300	97	1.3	1.7
Quality—Common	16.9	17.4	17.15	38	25	755	730	18	10.49	109	160	192	221	241	268	300	336	367	405	439	97.5	1.6	.9
Target	16.4	18.2	17.3	38	25	756	735	18	10.40	95	138	181	214	246	275	300	334	365	401	428	97.5	1.5	1
Silver Flash	16.7	16.6	16.65	38	25	754	725	21	12.61	93	138	174	205	214	250	275	297	320	349	374	97	1.5	1.5
Shell—Common	16.73	17.9	17.31	38	25	754	730	18	10.40	111	154	194	226	252	275	300	324	349	378	401	97	1.4	1.6
Shell—H. T	16.6	17.05	16.83	38	25	754	730	21	12.47	99	156	181	210	239	259	279	298	322	347	376	97.5	1.1	1.4
Johnson—Common	17.3	16.85	17.08	38	25	753	730	18	10.54	102	154	196	230	257	284	316	349	378	410	437	97	1.3	1.7
Johnson—H. T	16.9	17.4	17.15	38	25	750	710	21	12.24	102	144	172	196	219	235	253	291	302	336	385	98	1.1	.9
Indian—Common	18.35	17.3	17.83	38	25	749	730	18	10.09	108	162	199	226	259	280	302	325	354	390	430	97	1.7	1.3
Indian—Common	16.9	17.3	17.1	30	25	757	730	18	10.53	108	162	199	226	259	280	302	325	354	390	430	97	1.7	1.3
Indian—Common	15.5	16.5	16.0	38	40	754	730	18	11.25	108	162	199	226	259	280	302	325	354	390	430	97	1.7	1.3
Indian Red	17.2	18.1	17.65	38	25	753	735	21	11.33	102	160	192	221	241	262	280	302	329	367	414	97	1.6	1.4
White Rose	16.8	17.28	17.04	38	25	750	735	21	12.32	117	174	210	234	252	275	293	315	342	378	415	97	1.6	1.4
Ethyl	17.45	17.5	17.48	38	25	755	735	21	12.01	111	171	207	235	257	279	304	325	349	383	421	97	1.2	1.8
Aerolene	17.45	18.1	17.78	38	25	748	780	21	11.25	131	189	212	228	248	271	289	307	327	370	430	97.5	1.6	.9

PREPARATION OF "ACTIVE" MAGNESIUM CARBONATE FROM MAGNESITE.

FRANK C. MATHERS and WALTER VASHON EAGLESON, Indiana University.

Magnesium carbonate, made by precipitation, will cause lime plaster to set quickly.[1] A quick setting plaster is highly desirable but the cost of manufactured magnesium carbonate is too great for commercial use. No mechanical method of grinding or treating the mineral magnesium carbonate or magnesite produces a material of sufficient activity to be valuable. The purpose of the research reported here was to study methods of obtaining, by chemical treatment, a suitable magnesium carbonate for this use with lime in plasters.

Outline of the Work. The mineral magnesium carbonate or magnesite was changed to magnesium oxide by heating or "burning." The oxide was then changed to the hydroxide by soaking in water. This hydroxide was changed to the carbonate by suitable treatment with carbon dioxide. Magnesium carbonate thus prepared, was found suitable for making a "quick set" lime plaster.

Review. Anderson[2] found that the temperature at which magnesium carbonate is burned affects the rate of solution in water. In general, the rate of solution increases to a maximum and then decreases again as the temperature and the time of burning are increased. Only samples of pure manufactured magnesium carbonate and not the mineral were used.

Campbell[3] found that magnesium carbonate was completely decomposed at 600° C. Magnesium oxide produced by burning at 600 to 800° C. hydrated completely in three days. A reduced rate of hydration set in for magnesium oxide burned at 1000° to 1100° C. Magnesium oxide burned at 1450° C. (the temperature of the cement kiln) was only about 61 per cent hydrated after soaking in water for 18 months. Samples burned at 1000° C. hydrated completely in three months. After six years, samples burned at 1300° C. were only 85 per cent hydrated, samples at 1400° C. were 81 per cent hydrated and samples at 1450° C. were only 70.3 per cent hydrated.

Jesser[4] prepared the most active magnesium oxide by burning at a temperature just sufficient to liberate the carbon dioxide.

Grunwald[5] separated the light calcined magnesium oxide from the

[1] U. S. Pat. No. 1,604,575 and 1,607,473.

[2] J. Chem. Soc., *87*, 257 (1905).

[3] J. Ind. Eng. Chem., *1*, 665 (1909); *10*, 595 (1918).

[4] U. S. Pat. No. 1238147; Chem. Abst., *11*, 3102 (1917).

[5] U. S. Pat. No. 1285683, 1361324 and 1361866; Chem. Abst., *13*, 251 (1919) and *15*, 579 (1921).

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dead burned by sedimentation in water. The magnesium hydroxide, thus prepared, was then treated with carbon dioxide to make "light" magnesium carbonate.

Schurecht[6] found that the tendency of dead burned magnesium oxide to hydrate decreased as the temperature of burning increased.

Monhaupt[7] obtained 9.7 to 11.3 per cent of magnesium oxide in solution as the bicarbonate by passing carbon dioxide through a suspension of magnesium hydroxide.

Berkurts[8] made "magnesia alba" (basic magnesium carbonate) by treating slightly burned dolomite under 5 to 6 atmospheres pressure of carbon dioxide. The solution of magnesium bicarbonate was filtered from the insoluble calcium carbonate. Magnesia alba was precipitated from the filtrate by boiling. The magnesium carbonate from unignited dolomite will not readily dissolve in an aqueous solution of carbon dioxide.

The Austro-American Magnesite Co.[9] found that high reactivity towards magnesium chloride was obtained by burning above the lower limit for caustic magnesia with increased steam in the burning atmosphere.

Sisson[10] treated light calcined dolomite with sea water until all the calcium oxide was dissolved as calcium chloride by the magnesium chloride with simultaneous precipitation of an equivalent amount of magnesium hydroxide. This residue of magnesium hydroxide was finally carbonated.

Simon[11] treated burned dolomite with carbon dioxide and obtained magnesium bicarbonate in solution. Magnesium carbonate was obtained from this solution by boiling.

Materials Used. The sources of the magnesite used in these experiments were unknown. Two different samples were used. Duplicate experiments using the two different samples showed no noticeable differences in final results.

The calcination or the burning of the magnesite was done in an accurately controlled Hoskins furnace for all moderate temperatures. The calcination was done in a platinum crucible with a Meker burner for the temperature of 1000° C.

Experimental. The first experiments were made to determine the influence of the following conditions upon the completeness with which the magnesium oxide would hydrate with water: the fineness of grinding of the original magnesite; the temperature and the time of burning; and the time of soaking the magnesium oxide in water.

[6] J. Am. Ceram. Soc., *4*, 127 (1921).

[7] Chem. Ztg., *28*, 868 (1904). J. Chem. Soc. (Abst.) *86*, 731 (1904).

[8] Arch. Pharm. (3) *18*, 429, and *19*, 13. J. Chem. Soc. (Abst.) *42*, 13 (1882).

[9] Ger. Pat. No. 291686 (1913).

[10] Brit. Pat. No. 24134 (1906). Chem. Abst., *2*, 1758 (1908), Fr. Pat. No. 383407 (1907). Chem. Abst. *3*, 2358 (1909).

[11] Brit. Pat. No. 176785 (1922). Chem. Abst. *16*, 176 (1922).

TABLE I. Relation of Time of Calcination (at 700° C.) and of Hydration to Degree of Hydration. (The temperature of calcination was 700° C. and the magnesite was ground to 100 mesh.)

Time of Calcination	Time of hydration or soaking of the oxide	Completeness of hydration
1 Hr.	24 Hrs.	94.8%
1 Hr.	48 Hrs.	94.9%
1 Hr.	72 Hrs.	95.4%
1 Hr.	96 Hrs.	95.4%
2 Hrs.	24 Hrs.	94.0%
2 Hrs.	48 Hrs.	94.9%
2 Hrs.	96 Hrs.	95.3%
2 Hrs.	120 Hrs.	94.3%
3 Hrs.	24 Hrs.	94.6%
3 Hrs.	48 Hrs.	99.5%
3 Hrs.	92 Hrs.	95.3%
3 Hrs.	114 Hrs.	95.5%
4 Hrs.	24 Hrs.	95.6%
4 Hrs.	48 Hrs.	95.8%
4 Hrs.	72 Hrs.	95.9%
4 Hrs.	96 Hrs.	96.1%

This table shows that the degree of hydration is above 94.8 per cent for all samples whether burned one hour or four hours. The degree of hydration was as high after 24 hours soaking as after 96 hours. It should be noted that burning for four hours gave just as active an oxide as did burning for only one hour.

TABLE II. Relation of Time of Calcination (at 1000° C.) and of Hydration to Degree of Hydration.

The conditions were the same as for Table I except that the temperature of calcination was 1000° C., in platinum crucibles with a Meker burner.

Time of Calcination	Time of hydration or soaking of the oxide	Completeness of hydration
0.5 Hr.	24 Hrs.	88.0%
0.5 Hr.	48 Hrs.	93.1%
0.5 Hr.	72 Hrs.	93.5%
0.5 Hr.	96 Hrs.	94.3%
1 Hr.	24 Hrs.	95.6%
1 Hr.	48 Hrs.	94.8%
1 Hr.	72 Hrs.	91.2%
1 Hr.	91 Hrs.	92.0%
2 Hrs.	24 Hrs.	92.8%
2 Hrs.	48 Hrs.	88.8%
2 Hrs.	68 Hrs.	90.0%
2 Hrs.	115 Hrs.	90.5%
3 Hrs.	24 Hrs.	83.8%
3 Hrs.	48 Hrs.	88.3%
3 Hrs.	72 Hrs.	91.4%
3 Hrs.	96 Hrs.	91.2%

This table shows that calcination at 1000° C. gave somewhat less active magnesium oxide than did the calcination at 700° C. The most

active magnesium oxide was made by calcination at 1000° C. for only one-half or one hour. Also this magnesium oxide became more than 91.2 per cent hydrated by soaking for 24 hours except in one case which was evidently experimental error. Increase in the time of burning to two and to three hours decreased the activity of the oxide until the percentage of hydration by soaking was from 83 per cent up. It therefore seems that 1000° C. for one-half to one hour is an entirely satisfactory condition for making an active magnesium oxide as tested by its activity towards water.

TABLE III. Relation of Time of Calcination (at 1000° C., with Meker Burner) and of Hydration to Degree of Hydration, using Magnesite of 10 mesh size.

Time of Calcination	Time of hydration or soaking of the oxide	Completeness of hydration
0.5 Hr.	24 Hrs.	94.9%
0.5 Hr.	48 Hrs.	95.6%
0.5 Hr.	96 Hrs.	97.0%
1 Hr.	24 Hrs.	94.2%
1 Hr.	48 Hrs.	93.6%
1 Hr.	72 Hrs.	95.0%
1 Hr.	96 Hrs.	94.9%
2 Hr.	24 Hrs.	92.5%
2 Hrs.	48 Hrs.	92.4%
2 Hrs.	72 Hrs.	92.5%
2 Hrs.	115 Hrs.	93.6%

This table shows that the magnesium oxide made at 1000° C. for two to four hours was a little more active than was the magnesium oxide of 100 mesh prepared under the same conditions.

TABLE IV. Relation of Time of Calcination (at 700° C.) and of Hydration to Degree of Hydration, using Magnesite of 10 mesh size.

Time of Calcination	Time of hydration or soaking of the oxide	Completeness of hydration
1 Hr.	24 Hrs.	94.8%
1 Hr.	48 Hrs.	94.4%
1 Hr.	72 Hrs.	95.7%
2 Hrs.	24 Hrs.	92.9%
2 Hrs.	48 Hrs.	94.4%
2 Hrs.	72 Hrs.	94.9%
3 Hrs.	24 Hrs.	92.0%
3 Hrs.	48 Hrs.	93.2%
3 Hrs.	72 Hrs.	94.0%
3 Hrs.	115 Hrs.	93.7%

There was no noticeable effect due to the increase in size from 100 mesh to 10 mesh when the burning temperature was 700° C.

TABLE V. Relation of Time of Calcination (at 1000° C., with a Meker burner) and of Hydration to Degree of Hydration, using pieces of Magnesite of 1-2 cm. Diameter.

Time of Calcination	Time of hydration or soaking of the oxide	Completeness of hydration
0.5 Hr.	23 Hrs.	96.8%
0.5 Hr.	68 Hrs.	95.0%
0.5 Hr.	115 Hrs.	97.3%
0.5 Hr.	139 Hrs.	97.5%
1 Hr.	20 Hrs.	94.62%
1 Hr.	68 Hrs.	93.8%
1 Hr.	115 Hrs.	94.7%
1 Hr.	139 Hrs.	95.6%
2 Hrs.	24 Hrs.	93.0%
2 Hrs.	48 Hrs.	92.6%
2 Hrs.	72 Hrs.	91.4%

The activity of the oxide is greater for the shorter periods of calcination and is appreciably greater than for the smaller sizes under the same conditions. The maximum percentage of hydration was 97.3.

TABLE VI. Relation of Time of Calcination (at 1000° C., with a Meker burner) and of Hydration to Degree of Hydration, using pieces of Magnesite 4-5 cm. Diameter.

Time of Calcination	Time of hydration or soaking of the oxide	Completeness of hydration
0.5 Hr.	24 Hrs.	91.9%
0.5 Hr.	60 Hrs.	92.1%
0.5 Hr.	96 Hrs.	92.3%
1 Hr.	24 Hrs.	97.6%
1 Hr.	48 Hrs.	97.8%
1 Hr.	96 Hrs.	98.0%

One hour of calcination gave magnesium oxide which showed above 97.6 per cent of hydration. With 0.5 hour calcination, the results were lower, evidently due to incomplete burning.

Addition of sodium chloride to the crucibles during the burning of the magnesite did not change the activity of the magnesium oxide.

A summary of the above tables shows that perhaps the most satisfactory conditions were lumps 4-5 cm. in diameter burned at 1000° C. for one hour. The completeness of hydration of the oxide thus formed was 97.6 per cent, or more.

Carbonation of the Hydrated Magnesia. The magnesium hydroxide, prepared as shown in the foregoing experiments, was treated in an aqueous suspension with carbon dioxide. The degree of carbonation was determined by measuring the carbon dioxide evolved from the dried, (100° C.) carbonated material in a gas evolution apparatus. It is likely that 27 per cent carbon dioxide would represent as complete carbonation as could be expected judging from the fact that the magnesium carbonate, in the store room, showed this per cent of carbon dioxide.

Preliminary experiments soon showed that only very slight carbonation was obtained when carbon dioxide, under slight pressure, acted upon an aqueous suspension, if the containing vessel or flask was not shaken. The pressure of the carbon dioxide in these experiments was equal to the height of 74 cm. of 1:1 water and hydrochloric acid in the carbon dioxide generator. The most important factor in securing rapid carbonation was found to be agitation or rapid shaking of the flask while the carbon dioxide was being introduced. The method of agitation or of shaking was as follows: The flask with the rubber tube conveying the carbon dioxide attached, was clamped rigidly into a box. A wooden tongue attached this wooden box to an eccentric on a water motor. The box itself was suspended from a cross bar by two parallel wires in such a way that the box would be swung back and forth by the water motor about 60 times per minute. This agitation on one sample gave 34.8 per cent of carbon dioxide as compared to 7 per cent for a duplicate, minus the agitation.

TABLE VII. Effect of Time on Degree of Carbonation.

(Ten mesh particles of magnesite were calcined with a Meker burner at 1000° C. for one hour. These samples were hydrated by soaking in water for 24 hours. This magnesium hydroxide was treated with carbon dioxide with agitation.)

Time of carbonation	Carbon dioxide in the final dried material
24 Hrs.	23.65%
48 Hrs.	30.75%
72 Hrs.	34.87%

These results show that quite long periods of carbonation are necessary and that the percentage of carbon dioxide in the carbonated material increases as the time of carbonation increases. The sample carbonated for only 24 hours contained tiny grains of hard material which appeared to be the uncarbonated centers of the small lumps. The material carbonated for 48 hours contained fewer of these hard particles and the 72 hour material apparently contained none. It is likely that the agitation rubbed the magnesium carbonate from the surfaces of the magnesium hydroxide particles as fast as formed, thereby exposing fresh magnesium hydroxide to the carbon dioxide. This explains why the percentage of carbon dioxide was so small in the case of the unagitated material.

TABLE VIII. Effect of Time on Degree of Carbonation.

(Magnesite pieces 1-2 cm. in diameter were burned at 1000° C. for one hour with a Meker burner and then hydrated for 24 hours.)

Time of carbonation	Carbon dioxide in the final dried material
24 Hrs.	36.72%
48 Hrs.	27.07%
72 Hrs.	33.59%
96 Hrs.	24.75%

These results are somewhat difficult to explain but the variations are thought to be due to inability to get average samples. The highest percentage of carbon dioxide was in the material carbonated for only 24 hours. In this material, the uncarbonated cores or centers were large enough that they could be picked out completely whereby only the fine, completely carbonated particles were actually analyzed. These uncarbonated centers were rounded like pebbles in running streams. As the time of carbonation increased, these lumps became smaller and hence were more difficult to pick out. Low results on per cent of carbon dioxide are therefore attributed to incomplete separation of the unhydrated portions.

A sample of very fine magnesium hydroxide was made by grinding some of the magnesium oxide, burned at 1000° C. with a Meker burner, until the particles floated in water. These fine particles, carbonated for 15 minutes, contained 22.7 per cent of carbon dioxide and after 30 minutes of carbonation the per cent of carbon dioxide was 30.9. Increased time of carbonation to 24 hours did not change the value from this beyond experimental error. Also decrease in time of burning to one-half hour and increase in the time of hydration to 48 hours were without effect.

TABLE IX. Effect of Time of Calcination, Hydration and Carbonation on Degree of Carbonation.

Time of calcination	Time of hydration	Time of carbonation	Carbon dioxide in final dried material
1 Hr.	24 Hrs.	0.25 Hr.	22.76%
1 Hr.	24 Hrs.	0.5 Hr.	30.91%
1 Hr.	24 Hrs.	0.75 Hr.	31.84%
1 Hr.	24 Hrs.	1.5 Hr.	32.04%
1 Hr.	24 Hrs.	3 Hrs.	32.37%
1 Hr.	24 Hrs.	12 Hrs.	31.37%
0.5 Hr.	48 Hrs.	24 Hrs.	29.45%
1 Hr.	48 Hrs.	24 Hrs.	31.64%

Carbonation was also tried by bubbling the carbon dioxide through the aqueous suspension of the floated magnesium hydroxide in an open beaker. The magnesium hydroxide had been previously hydrated for 24 hours. The contents of the beaker were stirred continuously with a glass stirrer. After 24 hours the percentage of carbon dioxide was only 25. Another sample of the floated magnesium hydroxide was carbonated under pressure for three hours but the flask was shaken only at intervals. The percentage of carbon dioxide was only eight. This clearly shows the necessity for continuous and vigorous shaking. An attempt at carbonation in a ball mill during grinding by bubbling the carbon dioxide through the wet mix gave only 19.5 per cent. A sample of floated magnesium hydroxide was carbonated under pressure at 80° C. for 45 minutes. The result was only 19.8 per cent carbon dioxide. This was not as good as results at room temperature.

Activity of the Magnesium Carbonate in Promoting Quick Setting of Lime Plaster. The magnesium carbonate used contained 34.6 per cent

of carbon dioxide. The plasters as tested contained 33.3 per cent hydrated lime, 66.6 per cent sand, and 1.6 per cent of the magnesium carbonate.

A blank was made as above except without magnesium carbonate. Magnesium carbonate (Merck) from the storeroom was also tried. The blank was mixed with 34 ml. of water and the others with 36 ml. of water for each 100 grams of the plaster.

The magnesium carbonate made in this research produced a hardening in 45 minutes and a set in three hours (Gilmore needle). In three hours the Merck's magnesium carbonate had only started the hardening. The blank never set.

SUMMARY.

"Active" magnesium carbonate can be easily formed as follows: 1. Burn magnesite at 1000° C. for one-half hour if the pieces are 100 mesh, or for two hours if the pieces are 4-5 cm. in diameter. 2. Hydrate this oxide by soaking for 24 hours in water. 3. Carbonate this hydroxide by treating with carbon dioxide under slight pressure but the material being carbonated must be vigorously shaken or agitated during the time of carbonation. 4. The length of time of carbonation depends upon the size of the pieces of the magnesium hydroxide. If the magnesium hydroxide pieces are 4-5 cm. in diameter perhaps 72 hours will be required. If the particles of the magnesium hydroxide are fine enough to float in water, carbonation is fairly complete in one-half hour.

Calcium hydroxide containing 4 per cent of its weight of this magnesium carbonate produces a plaster that will set in three hours.

COMPARISON OF RUST PROTECTION OF IRON BY ZINC, BY CADMIUM, AND BY ZINC-COPPER ALLOYS AND THE ELECTRODEPOSITION OF SUCH ALLOYS.[1]

FRANK C. MATHERS[2] and RUSSEL L. HARDY.[3]

ABSTRACT.

Deposits of cadmium upon iron have recently become very extensively used especially in the automobile industry. Such deposits render the iron rust proof and are much more ornamental or decorative than are deposits of zinc. This paper reports attempts to measure the relative protection against rust given by zinc, by cadmium, and by zinc-copper alloys.

Zinc gives fine protection to iron as long as any considerable amount of the zinc coating remains on the iron. Zinc itself is so strongly anodic to iron and most other commercial metals that it reacts faster than is needed for the purposes of protection. Cadmium is nearer to iron than is zinc in the electrochemical series but it is still anodic to the iron. Therefore cadmium gives longer protection than does an equal thickness of the zinc, because the cadmium, being less active or less anodic, does not dissolve or corrode so rapidly. A zinc-copper alloy of about 15 per cent copper has nearly the same single potential or solution pressure as cadmium; hence it was thought that such an alloy might give as durable protection as does the cadmium. A survey of the literature indicates that such a thing might be possible. However, only actual salt spray tests could determine this point. Such an alloy might not dissolve or corrode homogeneously. If a coating rich in copper was finally left on the iron, the single potential might reverse. If this happened, the iron might become anodeic and its rate of corrosion would be increased.

Descriptions of experiments to determine the relative rustproofing power of zinc-copper alloys were not found. However, statements that zinc-copper alloys might be used for rustproofing were found. Cowper Coles (Brit. Pat. No. 154,108, Feb. 24, 1920) used a 50 per cent zinc-copper alloy. This alloy was electrodeposited from a potassium copper cyanide bath to which zinc compounds were constantly added. The patent also states that small zinc anodes might be used. Law[4] describes an alloy of 25 per cent copper and 75 per cent zinc that was used to protect iron and steel.

[1] Part of the work for the A. M. degree at Indiana University.

[2] Professor of Chemistry at Indiana University.

[3] Chemist for Ohio Hydrate and Supply Co., Woodville, O.

[4] "Alloys," G. Griffin & Co., (1919).

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

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Zinc[5] containing from 0 to 13 per cent of copper has about the same solution tension as pure zinc. With 15 per cent of copper there is a sudden drop in potential.

The E. M. F. of the cell zinc-copper alloy/zinc sulphate/potassium chloride/mercury drops 0.07v. by increasing the copper from 0 to 32 per cent.[6]

Zinc containing 0.19 per cent of copper dissolves as rapidly in acids as when the impurity is arsenic or antimony.[7]

However, the corrosion of the zinc alloy in 5 per cent sodium chloride was uniform for varying amounts of lead, iron, cadmium, arsenic, antimony, tin and copper. This uniformity of action was probably due to a protective coating of hydrated zinc oxide.

Electrodeposition of Zinc-Copper Alloys. No formula was found for a bath from which to deposit electrolytically an alloy of zinc containing small amounts of copper. The use of zinc-copper anodes of the desired composition in the ordinary brass baths did not give satisfactory results.

A pair of anodes, one of pure zinc and one of yellow brass, was hung in each side of the plating bath. By suitable electrical connections operated by an eccentric, the current was automatically changed every minute or two from the two zinc anodes to the two brass anodes and then, after an interval, back to the zinc anodes again. By careful regulation of the relative periods during which the current was on the brass anodes and on the pure zinc anodes, it was possible to control the composition of the bath and thereby obtain deposits of any desired composition up to 15 or 20 per cent copper. The composition of the bath used was 6 grams of sodium cyanide, 4 grams of zinc cyanide, 1 gram of copper cyanide and 4 grams of sodium hydroxide per 100 ml. (8 oz. sodium cyanide, 5.1 oz. zinc cyanide, 1.3 oz. copper cyanide and 5.1 oz. of sodium hydroxide per gal.). The current density at the cathode was 0.3 amp/sq. dm. (2.8 amp./sq. ft.). The bath was run at room temperature. One third of an ounce of metal per square foot (1.1 grams/sq. dm.) was deposited. This is the thickness recommended[8] for best commercial work.

The length of time in the salt spray before any rust appeared on the pure zinc coated pieces was taken as 100. The hours of protection afforded by the other coatings under the same conditions in the salt spray were compared to this value.

The time of resistance to rusting in the salt spray varies with the conditions of operation of the salt spray. However all these results are strictly comparable, as they were all obtained under the same conditions. Several methods of operating the salt spray were tried. A convenient form was a wheel revolving in the 5 per cent salt solution. This wheel splashed the solution upon the pieces to be tested. This spray acted more slowly than a spray blown by air. The same relative results were obtained for the three types of coatings regardless of the conditions of the operation of the spray.

[5] Pushin, J. Russ, Phys. Chem. Soc., *39*, 353.
[6] Gambi, Rend. r. ist Lombardo (2) *48*, 826.
[7] Prost, Bull. Soc. Chim. Belg., *28*, 94.
[8] Proctor, Metal, Ind., *21*, 326 (1923).

The deposits of cadmium and of pure zinc were made electrolytically from well known cyanide baths. The thickness of the deposits on the various test pieces were determined by calculation from the ampere hours used and the surface being covered and the density of the metal being deposited. Careful experiments with a coulometer were made with each bath to determine its electrochemical efficiency for use in the above calculations.

The single potential values were made with the ordinary potassium chloride calomel cell.

The results of the test are summarized in Table I.

TABLE I. Relative Protection against Rust of Various Metals and Alloys.

Composition of the coating or deposit	Single potential of test piece		Protection (in per cent, with pure zinc as 100)
	Before salt spray	After rusting	
21.32% copper	−0.36	+0.26	.....
14.88% copper	−0.51	+0.21	85.52
9.49% copper	−0.49	+0.11	85.72
Pure zinc	−0.57	+0.08	100.
Pure cadmium	−0.30	+0.19	176.
Red brass	.....	.....	37.5

CONCLUSIONS.

These experiments show that the presence of copper in the zinc deposit on iron lessens the time of protection in the salt spray.

Cadmium gives almost twice as long protection as does an equal weight of zinc.

If only the cost of the actual metal for the coating is considered, the protection by the cadmium at 75 cents per pound costs about seven times as much as the protection from the zinc at 8 cents per pound.

This paper gives a method of controlling the composition of electrodeposited alloys by using anodes of two different compositions. The current is automatically shifted back and forth between the anodes of the different compositions. A proper regulation of the period during which each kind of anode is in the circuit will give the desired composition to the bath and to the deposit.

ESTERIFICATION IN THE PRESENCE OF ANHYDROUS SALTS.

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The usual method of producing esters involves the removal of water, which is one of the products of the reaction between alcohol and acid. Equilibrium is shifted toward the production of ester by the removal of water. Sulphuric acid is often employed for this purpose, but hydrochloric acid is also frequently used.

The role that such an acid plays in promoting ester formation, although not well understood, cannot be wholly due to the combination of sulphuric or dry hydrochloric acid with water. Either the acid molecule, or some part of it, plays the role of catalyst. The question of the nature of acid catalysis and the active catalysing agent is still one that may be considered open for investigation.

Many salts crystallize from water in definite forms and combined with definite numbers of water molecules per molecule of compound. When such salts are dehydrated, they become excellent dehydrating agents, and, as such, they should promote esterification and all similar reactions in which water is one of the products. There are, however, several questions that arise in using anhydrous salts for this purpose. Do the salts act as catalysts? If so, is the catalytic effect due to the salt itself? Do the salts hydrolyse to produce acids which act as catalysts? Will the salts accelerate the reaction at temperatures above the dehydration temperatures of the crystalline substances? How does the temperature at which the salt is dehydrated affect its use in promoting esterification? How does the catalytic effect of the anhydrous salt compare with its efficiency in other instances of its use as an agent of dehydration and dessication? Is there any relation between the number of molecules of water in the crystalline substance and the effect of the anhydrous salt upon ester formation? What salts are most effective?

This paper does not attempt to answer all these questions. It is the hope of the writers, however, to add to the present knowledge of this reaction.

Various anhydrous salts have been used in the esterification of organic acids and ethyl alcohol by Bogojawlensky and Narbutt[1] and by Haberman and Brezina[2] and by Haberman and Kurtenacher.[3] The salts employed by these workers were sulphates with few exceptions. Ferrous, nickel, copper, manganese and zinc sulphates were found effective. Sodium

[1] Bogojawlensky and Narbutt: Esterificirungsversuche, *38*, 3344, (1905).

[2] Haberman and Brezina: Beitrage zur Darstellung und Kenntnis des Essigathers, J. prakt. Chem., *80*, 349, (1909).

[3] Haberman and Kurtenacher: Beitrage zur Darstellung und Kenntnis des Essigathers, J. prakt. Chem., *83*, 541, (1910).

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

sulphate was found to have no effect. Potassium pyrosulphate gave very good results. Various aliphatic and aromatic acids were esterified with ethyl alcohol in the presence of these salts.

EXPERIMENTAL.

Apparatus. Most of the experiments of the writers were made in a thermostat of about fifteen gallons capacity; the water in it was continuously agitated, and the temperature was maintained at 45° C.

Some of the reactions were carried out in a water bath large enough to accommodate four flasks to which reflux condensers were attached. The temperature of this bath was kept at the boiling point of water.

Some experiments were made in which the anhydrous salts were placed in an electric furnace which was heated to a temperature above that of the dehydration point of the salts. The vapors of the acid and alcohol were passed over the catalyst very slowly. Both reactants were introduced into an auxiliary furnace, where they were vaporized. The vapors were then passed through the second furnace, where the reaction occurred. The gaseous products were led through a condenser. Each reaction was run as long as any product could be condensed. The tube which contained the salts and through which the reacting vapors were made to pass was of quartz.

Materials. Absolute alcohol was prepared by treating 96 per cent stock alcohol with quicklime. Calcium hydroxide was heated slowly to a dull red heat. About 300 grams of the product were added to 500 cc. of alcohol, and the mixture was refluxed for four hours. The alcohol was then distilled with great care to prevent overheating. Anhydrous copper sulphate was used to test for water in the product. The alcohol was not used unless the sulphate remained colorless after two hours.

About three liters of C. P. acetic acid were placed in a freezing mixture of salt and ice. After the solid acid had collected on the walls of the bottle, the liquid was poured off and placed in another freezing mixture, where it was left for two hours. The final liquid fraction was poured off, and the two solid portions were mixed. The specific gravity was measured with a pycnometer.

The normal hydrochloric acid solution was standardized against potassium acid phthalate. The normal potassium hydroxide solution was made up in 50 per cent redistilled stock alcohol.

The salts were dehydrated in an iron container, which was carefully cleaned and sanded after each dehydration. This container and its contents were heated in an electric furnace. The temperature was noted and carefully controlled in every case.

Experimental Procedure. Alcohol and acid were placed in separate burettes, care being taken that no more than the unavoidable amount of air should come into contact with them at any time. Ten ml. of the acid was run into a long necked flask of about 50 ml. capacity; 10.5 ml. of absolute alcohol was added. Ten grams of the anhydrous salts were added, since this amount was well above the amount that is theoretically required to combine with the water which is produced by the reaction of the amounts of acid and alcohol indicated above. These salts were all

dehydrated at temperatures slightly above that which is necessary to drive off all the water which is combined with them in the crystalline state.

After the proper mixtures were prepared, the flasks and their contents were weighted and suspended from a wire that extended across the constant temperature bath. The flasks were completely submerged, with the exception of the extreme ends of the long necks.

When definite periods of time had elapsed, the flasks were removed; the contents were cooled; and a two cubic centimeter sample was pipetted and transferred directly to a flask, where a few drops of phenolphthalein were added. The sample was titrated immediately with potassium hydroxide solution. The potassium hydroxide, standardized in reference to the acid used, gave the amount of the free acid that the sample contained. From these results the per cent of esterified acid was calculated. To avoid errors that might be caused by the presence of small amounts of the salts, the ester was saponified by treatment with excess potassium hydroxide at 90°-100° C. for four hours. The amount of hydroxide used in the saponification permitted the calculation of the amount of ester and, hence, the per cent of the acid which had been esterified.

DATA.

A series of preliminary experiments was made with a mixture of 24.5 ml. of absolute alcohol and 16.1 ml. of glacial acetic acid. This mixture was refluxed in the presence of 10 grams of different anhydrous salts. The results listed in Table I were found after the mixture had

TABLE I. Preliminary Preparation of Ethyl Acetate (Temperature 100°C.)

Catalyst	Time Refluxed (in hours)	Time Allowed to stand after refluxing (in hours)	Yield (Per cent of Theory)
H_2SO_4	1	0	70.00
Blank	10	14	Slight odor
Alum	10	14	5.50
$CuSO_4$	10	14	7.60
$MnSO_4$	10	2	10.00
$MgSO_4$	10	2	19.00
$MgSO_4$	10	14	25.00
Alum	10	10.5	62.00
$ZnCl_2$	0	43.5	70.90
$CuSO_4$	0	0	0.00
$CuSO_4$	2	0	15.19
$CuSO_4$	4	0	19.19
$CuSO_4$	6	0	18.87
$CuSO_4$	8	0	21.25
$CuSO_4$	10	0	20.32
$CuSO_4$	0	14	23.75
$MgSO_4$	10	0	32.19
$MgSO_4$	0	14	35.00
$MnSO_4$	10	0	25.19
$MnSO_4$	0	10	27.00

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been allowed to react for the designated number of hours. These results were found by neutralizing the whole sample with a saturated solution of sodium carbonate. It was then placed in a separatory funnel. The ester was then salted out and separated from the water layer. The crude product was then distilled, and the portion that came over at 74°-76° C. was then collected and weighed.

The data presented in the following tables are arranged to show the effects of the different salts that were used. Table II gives the percentages of acetic acid that were esterified in different periods of time in the presence of various salts. These results are also represented graphically. The retarding effect of calcium sulphate is to be noted; all other salts in this series gave positive results. Copper sulphate was the most effective catalyst. All these salts were dehydrated at temperatures just slightly above the temperatures at which they are supposed to lose all their water of crystallization.

Table III shows the effect of the nature of the alcohol molecule upon the formation of the ester. The length of the chain of carbon atoms and the structure of the molecule are found to affect the reactivity of the molecule in the presence of anhydrous salts as elsewhere.

Table IV shows the effect of the structure of the acid molecule upon the formation of esters in the presence of anhydrous copper sulphate.

Table V shows the effect of the temperature of dehydration of the salts upon their action as catalytic agents. Cupric sulphate dehydrated at 130° C. is not as good a catalyst as the same salt after it has been dehydrated at 240°C. This salt does not lose all of its combined water until it has been heated above 130°C. The same is true of magnesium sulphate, which does not attain its full catalysing action until it has been dehydrated at temperatures above 200°C. It will also be noted that salts dehydrated at temperatures above those at which they are supposed to lose all water of crystallization are poorer catalysts than those which are dehydrated at the exactly required temperatures.

Table VI shows the amounts of esters formed when vapors of alcohol and acid were passed together over anhydrous salts in a quartz tube, which was heated to a temperature above the point at which the salt is completely dehydrated. The alcohol and acid were vaporized in an auxiliary furnace which was held at 130°C. The temperature of the furnace which contained the salt was held at 230°C. The marked differences in the catalytic influences of the different salts cause great variations in the amounts of ester formed in the different experiments.

TABLE II. Time-percentage Data With Reference to the Action of Various Anhydrous Salts on the Rate of Formation of Ethyl Acetate.

(Temperature 45°C.)

A. $CuSO_4$

Hours	Acid Esterified
12	47.43%
30	64.76%
48	70.97%
120	76.63%
168	82.67%
264	84.11%
360	84.11%

C. $CdSO_4$

Hours	Acid Esterified
12.5	8.46%
43	23.20%
96	50.26%
168	61.24%
768	63.49%

B. $Al_2(SO_4)_3 \cdot K_2SO_4$

43	40.63%
96	57.49%
120	62.61%
240	69.12%
792	75.06%

D. $MnSO_4$

12.5	6.42%
96	41.10%
168	43.33%
264	47.70%
336	53.42%

E. $Fe_2(SO_4)_3$

17	52.77%
72	60.35%
114	63.56%
384	63.56%

G. $CaSO_4$

72	16.33%
115	23.33%
264	36.45%
384	38.72%

F. $Al_2(SO_4)_3$

12.5	39.95%
48	56.86%

No samples could be obtained after 48 hours due to the absorption of all of the liquid by the solid.

H. Blank (No Catalyst)

24	9.72%
118	34.12%
552	47.32%

Fig. 1—Graphic presentation of results shown in Table II.

TABLE III. Esterification of Different Alcohols and Acetic Acid, with Copper Sulphate as Catalyst.

(Time 360 hours, Temperature 45°C.)

Alcohol	Yield (Per cent of Theory)
Ethyl	84.108
n-Butyl	61.800
iso-Butyl	60.560
Secondary Butyl	50.310
Tertiary Butyl	9.630

TABLE IV. Esterification of Different Acids and Ethyl Alcohol

(Time 360 hours, Temperature 45°C.)

Acid	Yield Per cent of Theory
Acetic	84.10
iso-valeric	82.48
n-valeric	81.62
Mono-chloro acetic	75.11
Propionic	49.71
iso-Butyric	48.33
n-Butyric	47.40
Di-chloro acetic	32.73

TABLE V. Temperatures of Dehydration of Salts and the Corresponding Effect on the Rate of Esterification of Ethyl Alcohol by Acetic Acid

(Time 4 hours, Temperature 100°C.)

Salt	Temperature of Dehydration	Acid Esterified
$CuSO_4$	Hydrated	23.74%
$CuSO_4$	130°C.	65.68%
$CuSO_4$	240	71.68%
$CuSO_4$	260	69.30%
$CuSO_4$	340	69.43%
$MgSO_4$	Hydrated	23.74%
$MgSO_4$	160	42.73%
$MgSO_4$	210	51.27%
$MgSO_4$	260	31.70%

TABLE VI. Esterification of Ethyl Alcohol by Acetic Acid in the Vapor Phase over Anhydrous Salts.

Temperature: Vaporizing Chamber....130°C.
Temperature: Reaction Chamber.....230°C.

Salt	Acid Esterified
Blank	1.26%
$K_2SO_4 \cdot Al_2(SO_4)_3$	20.92%
$Al_2(SO_4)_3$	39.37%
$CdSO_4$	0.55%
$MnSO_4$	2.36%
$MgSO_4$	0.00%

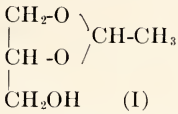
CONCLUSIONS

The action of anhydrous salts in promoting esterification cannot be assigned to one cause. It is in part due to the dehydrating action or water-withdrawing action of the anhydrous salt, an action which shifts the equilibrium towards the formation of ester. This cannot be the sole factor, however, for plaster of Paris is a retardant, and anhydrous sodium sulphate has no effect. Neither is there any relation between the number of molecules of water with which the salt will combine and its efficiency in catalysing the reaction. There seems to be no relation between the catalytic action of the salts and their commonly accepted efficiencies in dessication and dehydration. There is, however, a marked increase in the accelerating effect of the catalyst, when it is dehydrated at temperatures which are calculated to remove all rather than a part of the water of crystallization; and this accelerating effect is reduced when the salt has been heated to a high temperature. The latter effect approximates the condition of "dead burning" in the case of quicklime, which becomes unreactive towards water after it has been heated for some time at high temperatures. That there are other factors that must be considered in addition to the removal of water by the catalyst, is shown by the fact that copper sulphate and magnesium sulphate, not dehydrated, produce many times as much ester as can be produced in their absence. Salts also accelerate ester formation at temperatures above those at which they are able to combine with water.

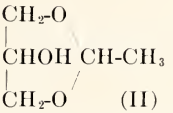
THE FORMULA OF ETHYLIDENE GLYCEROL.

J. A. NIEUWLAND and W. L. FOOHEY, University of Notre Dame.

Ethylidene glycerol is capable of existence in two isomeric forms. Because of their similarity in properties and their instability, no evidence was brought forward to show which of the following formulas should be considered as correct.



(I)



(II)

Hill and Hibbert[1] showed from partition experiments that both forms must be present in ethylidene glycerol made by either the acetylene or the acetaldehyde method of preparation.

Recent work by Hill, Hill, and Hibbert[2] has shown that glycerol acetal made from paraldehyde consists of 80 per cent (I) and 20 per cent (II), and that from the acetylene method (mercuric sulfate and sulfuric acid catalyst) is 64 per cent (I) and 36 per cent (II). Separation and identification of the isomers was made possible by benzoylation in pyridine and separation of the benzoates in cold ligroin.

Using as catalysts mercuric oxide and anhydrous fluo-acids, the authors have prepared ethylidene glycerol, as well as other cyclic acetals, from acetylene.

In our procedure care is taken not to allow the liquid to become hot, the maximum temperature being 37°C. Because of this and because we use a less strongly acid catalyst, our product contains less low-boiling material. This indicates a predominance of the 1-2 acetal (I).

Methylation of the acetal by adding sodium and treating with methyl sulfate gave a 76 per cent yield of the methyl ether, b.p. 145-151°C., d_4^{23} 1.0135, n_D 1.4155. This is identical with the product formed from glycerol a-methyl ether and acetylene, b.p. 145-147°C., d_4^{23} 1.0098, n_D 1.4145. This shows that the 1-2 compound is present in large quantity or that it is considerably more reactive than its isomer. Similar, but less certain evidence was obtained from the acetal of glycerol a-chlorhydrin.

From these evidences and from a comparison of the properties of our compounds with the pure isomers made by Hill, Hill and Hibbert,[2] we concluded that our product was in large proportion the 1-2 acetal (I).

TABLE I. INDICES OF REFRACTION.

1-3 Ethylidene glycerol[2]	1.4532
1-2 Ethylidene glycerol[2]	1.4413
"Ethylidene glycerol"[3]	1.4395
1-3 Ethylidene glycerol methyl ether[2]	1.4375
1-2 Ethylidene glycerol methyl ether[2]	1.4177
"Ethylidene glycerol methyl ether"[3]	1.4155

[1] Hill and Hibbert, J. Am. Chem. Soc., *45*, 3121, (1923).

[2] Hill, Hill, and Hibbert, ibid., *50*, 2242, (1928).

[3] As prepared by the authors.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

In order to check this, we benzoylated 39 g. of our product and separated the isomers. We obtained 5 g. of the crystalline benzoate (from 1-3 ethylidene glycerol) m.p. 86°C, and 18 g. of the liquid benzoate (from 1-2 ethylidene glycerol), b.p. 163°C. 11 mm. The ratio of the two isomers is then 1:3.6 or our product consists of 78 per cent 1-2 ethylidene glycerol (I) and 22 per cent 1-3 ethylidene glycerol (II).

Formation of (I) is thus shown to be favored by the use of fluo-acid catalyst and by keeping the liquid cool during the reaction.

CUPROUS CHLORIDE AS A CATALYST FOR ACETYLENE.

J. A. NIEUWLAND and W. L. FOOHEY, University of Notre Dame.

Neutral or acid solutions of cuprous chloride and alkali chlorides or ammonium chloride absorb acetylene, forming several derivatives according to conditions. Intermediate products are probably formed, the final products being given off when the mixture is heated.

When cuprous and ammonium chlorides are used in solution saturated with hydrogen chloride gas, vinyl chloride is formed in about 30 per cent yield. The addition of an organic solvent is necessary to keep the very volatile vinyl chloride in solution.

$$C_2H_2+HCl(CuCl,NH_4Cl)\rightarrow CH_2=CHCl$$

A mixture of cupric, cuprous and ammonium chlorides acts as a chlorinating agent. Acetylene passed into this solution forms the equilibrium mixture of *cis* and *cis-trans* dichlorethylenes, b.p. 54°C.

$$C_2H_2+2CuCl_2(CuCl,NH_4Cl)\rightarrow \begin{matrix} Cl & Cl \\ | & | \\ C & = & C \\ | & | \\ H & & H \end{matrix} +2CuCl$$

$$C_2H_2+2CuCl_2(CuCl,NH_4Cl)\rightarrow 2CuCl+\begin{matrix} H & Cl \\ | & | \\ C & = & C \\ | & | \\ Cl & & H \end{matrix}$$

Cuprous and cupric chlorides, with or without ammonium chloride saturated with hydrochloric acid, give on treatment with acetylene a mixture of unsymmetrical and *cis-trans* dichlorethylenes. This is interesting as being the only synthesis which gives one of the symmetrical compounds without the other, also in that an unsymmetrical chlorination product is formed from a symmetrical hydrocarbon. The unsymmetrical dichlorethylene is identified by its boiling point (37°C.) and from its forming chloracetyl chloride and a solid polymerized product on standing in contact with air. The *cis-trans* compound is identified by its boiling point (48°C.). The *cis* isomer, b.p. 60°C., is not present.

$$C_2H_2+2CuCl_2(CuCl,HCl)\rightarrow \begin{matrix} H & Cl \\ | & | \\ C & = & C \\ | & | \\ Cl & & H \end{matrix} +2CuCl$$

$$C_2H_2+2CuCl_2(CuCl,HCl)\rightarrow CH_2=CCl_2+2CuCl$$

After the products have been removed by heating, cupric chloride is regenerated by passing chlorine into the solution. Some cuprous chloride must be left in the solution for catalysis.

$$2CuCl+Cl_2\rightarrow 2CuCl_2$$

Solutions of cupric chloride in the absence of cuprous chloride do not absorb acetylene.

The mechanism of these reactions is unknown and will probably remain so until the constitution of chlorocupric acid ($HCuCl_3$ or $CuCl_2 \cdot HCl$) and chlorocuprous acid (H_2CuCl_3 or $CuCl \cdot 2HCl$) is more fully understood.

THE OXIDATION OF BENZYL ALCOHOL BY THE THREE ISOMERIC NITROCHLORBENZENES.

Robert E. Lyons and Guido H. Stempel, Jr., Indiana University.

This study of the oxidizing action of o,m,p-nitrochlorbenzenes in reaction with benzyl alcohol is a continuation of the work of Lyons with Smith,[1] Fletcher[2] and Pleasant,[3] concerning the reactions between various aromatic nitro compounds and alcohols, which has included determination of the optimum conditions for complete reaction and the qualitative and quantitative study of the course and extent of the reduction of the nitro compound and of the oxidation of the alcohol.

Karl Heumann[4] obtained 4-4′ dichlorazoxybenzene (M.P.155°C.) from p-nitrochlorbenzene by reaction with alcoholic potash, but was unable to reduce o-nitrochlorbenzene with this reagent.

Laubenheimer[5] successfully reduced m-nitrochlorbenzene with alcoholic potash to 3-3′ dichlorazoxybenzene (M.P. 97° C.)

A. V. Bloom[6] has studied the rate of reaction between potassium ethoxide and both o- and p-nitrochlorbenzene. He reports the formation of p-nitrophenetole and 4-4′ dichlorazoxybenzene from the para isomer, and o-nitrophenetole from the ortho isomer following a very slight and unsatisfactory reaction.

A study of the reaction, under somewhat different conditions and less complete quantitatively, between each of the three isomeric nitrochlorbenzenes and benzyl alcohol by Suter and Dains[7] has appeared since our experimental work was completed.

Experimental.

Apparatus: The reactions were carried out in the apparatus devised by Smith and Fletcher. The essential parts consist of a 500 ml., three necked, round Pyrex flask with a metal stirring rod, equipped with a mercury seal, entering the center neck of the flask. At the end of the rod of the mechanical stirrer is a riveted, folding blade, shaped to the inner surface of the flask, which permits it to fold back in line with the rod and to pass through the flask neck. A reflux, water cooled, condenser is fitted into one of the side necks and a dropping funnel into the other.

[1] L. T. Smith with R. E. Lyons, J. Am. Chem. Soc., *48*, 3156 (1926).

[2] W. A. Fletcher, Unpublished thesis (Ind. Univ.).

[3] R. E. Lyons and Meredith Pleasant. Paper presented at last meeting of Academy (Dec., 1928). To be published elsewhere.

[4] Heumann, Ber., *5*, 911 (1872).

[5] Laubenheimer, Ber., *8*, 1623 (1875).

[6] Bloom, Chem. Centralblatt, *92*, 1232 (1921).

[7] Suter and Dains, J. Am. Chem. Soc., *50*, 2733 (1928).

I. Para Nitrochlorbenzene and Benzyl Alcohol. For the initial trials the following procedure was used. Theoretical portions of benzyl alcohol, p-nitrachlorbenzene, and sodium hydroxide, corresponding to the equation

$$2C_6H_4ClNO_2+2C_6H_5CH_2OH \rightarrow C_6H_4ClN=NClC_6H_4+2C_6H_5COOH+2H_2O$$

were used, the amount of caustic being determined by the theoretical amount of 78 per cent sodium hydroxide necessary to convert the alcohol to the corresponding sodium alcoholate. The alcohol and the sodium hydroxide were first allowed to react for a few minutes at room temperature, and then a solution of the nitro compound in xylene (b.p. 139° C.) was allowed to drip into the reaction mixture. Heating was started as soon as all of the nitro compound had been added, and the temperature gradually raised to 60° C.

After the reaction had continued at this temperature for four hours, the mass was transferred to a flask and steam distilled to remove the solvent, xylene. The insoluble product, appearing as small orange-yellow nodules, was filtered out, dried, and weighed. The filtrate was then acidified with dilute (1:1) hydrochloric acid, the benzoic acid separating out as a white, flaky precipitate, which was filtered out, dried, and weighed, proper correction in the final estimated yield being made for the solubility of benzoic acid in water.

The reduction product was further purified for identification by crystallization from alcohol, in which its solubility was very small at room temperature but rather high at the boiling point of alcohol. The purification of the product from each of these preliminary trials gave orange needles which had a melting point of 156°, 156°, and 159° C., respectively. Since the melting point of 4-4′ dichlorazoxybenzene has been recorded in the literature as 155° C. and that of the corresponding azo compound as 185-186° C., it was assumed that the reduction had gone as far as the azoxy compound with the further formation of a small amount of azo product. Hence, the reaction apparently followed the equation

$$4C_6H_4ClNO_2+3C_6H_5CH_2OH \rightarrow 2C_6H_4ClN\overset{O}{\diagup\diagdown}NClC_6H_4+3C_6H_5COOH+3H_2O.$$

The first trials making it apparent that the reaction ran smoothly without any thermal decomposition, systematic trials were made to determine the optimum conditions, the factors indicated below being considered. Unless otherwise stated, theoretical proportions of the reacting materials were used according to the preceding equation.

(1) Temperature: The reaction mixture seemed to withstand a fairly high temperature without decomposition. Hence, trials were made at the boiling point of the solvent used, 139° C., the reduction being approximately 100 per cent at that temperature, whereas at 60° C. the reduction was only 66.6 per cent complete. The oxidation of the alcohol to benzoic acid showed the same variation.

(2) Amount of Caustic: Trials using respectively 18/23 and 26/23 of the theoretical amount of sodium hydroxide showed no differ-

ence in results. A much higher amount of caustic tended to induce slight decomposition.

(3) Amount of Solvent: Though immediate decomposition resulted when no solvent was present, an increase over the original amount required to dissolve the nitro compound did not change the final results.

(4) Time of Reaction: The first trials being made at 4 hours, it was determined than an increase in this time-period was of no value, and that a decrease down as far as one and one-half hours produced the same results as the four hour period.

(5) Amount of Alcohol: An increase in the amount of alcohol used produced no further reduction of the nitro compound, whereas the alcohol itself was reduced partially to benzaldehyde and partially to benzoic acid.

(6) Method of Initial Mixing: When the nitro compound was introduced dissolved in the solvent into the mixture of alcohol and caustic, the reduction product was a mixture of azo and azoxy compounds. When the nitro compound was introduced in its solid form in the mixture of the alcohol, caustic, and solvent, the reaction seemed to be retarded sufficiently that the whole process ran smoothly to the azoxy stage, with a corresponding quantitative oxidation of the alcohol to benzoic acid.

An attempt was then made to identify the mixed products obtained in the first few runs, using a method suggested by Snowden[1], whereby the melting points of various known mixtures of the two components were taken. However, this method fell short of our expectations, since the mixtures failed to give sharp melting points, the 50-50 mixture of azo and azoxy compounds varying, for example, over a range of 2.4° C. For an approximate determination, the following table, in which the average melting point is given, is satisfactory. Since the melting points of all reaction products were taken after the product had been crystallized from alcohol, we accordingly took the melting points of the crystals deposited from an alcoholic solution containing azo and azoxy compounds in the proportions named.

TABLE I. Melting Points of Mixtures of Azoxy and Azo Compounds

Azoxy Compound	Azo Compound	Melting Point	Azoxy Compound	Azo Compound	Melting Point
100%	0%	155.0°C.	50%	50%	163.9°C.
90%	10%	154.1°C.	40%	60%	169.5°C.
80%	20%	155.7°C.	30%	70%	173.0°C.
70%	30%	157.7°C.	20%	80%	176.7°C.
60%	40%	159.7°C.	10%	90%	181.2°C.
50%	50%	163.9°C.	0%	100%	185.5°C.

II. Meta Nitrochlorbenzene and Benzyl Alcohol. The same optimum conditions as determined for the para isomer were applied to the meta compound, with the result that it was reduced quantitatively to the pure 3.3′ dichlorazoxybenzene (m. p. 97°C.), with the complete oxidation of

[1] J. Phys. Chem., *15*, 841 (1911).

the alcohol to benzoic acid. Also, this reaction was found to run to completion at a much lower temperature than was the case in the para isomer, the autooxidation-reduction being 98.8 per cent, even at room temperature—25°C. Neither increase in temperature nor increase in the time-period induced any further reduction.

III. Ortho Nitrochlorbenzene and Benzyl Alcohol. When the conditions used successfully in the oxidation of benzyl alcohol by the para and meta nitrochlorbenzenes were applied to the ortho isomer, considerable thermal decomposition resulted immediately, the reaction being very violent. In an attempt to curb this decomposition, it was found that, by using a large excess of solvent and by introducing the caustic into a mixture of the other materials slowly, a product could be obtained from which a yellow orange substance could be extracted by means of petroleum ether. The best yield obtained by this method was 17.6 per cent of the theoretical.

The identification of this product was rather troublesome. Its crystals melted at 49° C. when obtained both from petroleum ether and from alcohol. Fractionation by crystallization was unsuccessful and no product corresponding to any of the reduction products to be expected could be obtained directly by reduction of the original nitro compound. Qualitative tests proved that the product contained either a nitroso, an azoxy, or an azo group. At the same time the melting point of the substance was materially raised by treating it with sulfuric acid—a method commonly used to convert an azoxy into the corresponding azo compound—indicating that we probably had, as before in the case of the para compound, a mixture of azo and azoxy compounds. A nitrogen determination by the Dumas method showed 9.91 per cent, as against 10.49 per cent required for the azoxy compound, a difference of 0.6 per cent. Since the compound in question volatilized very readily this difference was not considered surprising.

The yields of benzoic acid in these cases were all very low—15 per cent, or less. Some of the benzyl alcohol was oxidized to benzaldehyde, the distillates from the steam distillation of the reaction mixtures all showing the presence of benzaldehyde when tested with the Schiff reagent.

THREE CAVERN PICTURES.

CLYDE A. MALOTT, Indiana University.

Limestone caverns are natural subterranean runway voids which have been selectively formed below upland areas at one or more levels in limestone strata. Fundamentally they are forms resulting from water drainage through limestone beneath the surface. They had their origin in the insiduous percolation of groundwaters along structural control lines, such as joints and bedding planes. These waters, charged with carbonic acid, dissolved runways sufficiently large to permit streams to freely follow them, and the runways thus initiated have been further dissolved out and eroded by the streams which coursed through them. As runways of subterranean streams, either of the past or of the present, caverns are nearly horizontal in the direction of their length, though in their outlet directions they become lower, somewhat like surface streamways. It is probable that our larger caverns once served as subterranean conduits between swallow-holes of disappearing surface streams of upland areas and large springs which issued at lowland levels in the deeper valleys transecting the limestone upland. Caverns have been or are subterranean drainage routes.

What I have to say under the caption of this brief paper has as much to do with comparative impressions or ideas as with the descriptive phenomena of three limestone caverns in southern Indiana which I have repeatedly visited in the past few years in company with students. The caverns are the well known Wyandotte and Marengo caves of Crawford County, and a little known cave at the Wesley Chapel "Gulf" of Lost River, about two miles east of the village of Orangeville, Orange County. I shall discuss these in the reverse order in which they are mentioned.

Lost River disappears in a swallow-hole, or a series of them, in its channel on the upland limestone plain southeast of Orleans, Orange County, at an altitude of about 620 feet. Its waters issue from the terminus of a subterranean conduit near Orangeville, eight miles west, at an altitude of 490 feet. The drainage basin of Lost River above the first swallow-hole comprises about 60 square miles. Below the "sink" of Lost River the waters of many tributaries disappear in swallow-holes and greatly augment the waters which rise from the slimy pit at the terminus of the underground conduit. During times of heavy or continued rains the underground channel is filled to capacity, and excess waters pass through the "dry-bed" channel on the surface. The surface channel in its sinuous course traverses a distance of 21 miles between the first definite swallow-hole and the "rise" south of Orangeville. It appears that the sub-surface conduit runs west in a nearly direct line from the "sink" to the "rise." The length of the conduit is probably

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but little greater than the direct distance of eight miles. The directness of the sub-surface route is indicated by the presence of four large swallow-holes in the "dry-bed" channel where it repeatedly crosses the direct line of the "sink" and the "rise." From one of them the underground channel may be reached. The deeper and more abrupt sinkholes also occur along this direct line. Near Wesley Chapel a great "gulf" occurs, where an oblong area 600 feet wide and 1,100 feet in length has collapsed into the subterranean Lost River, forming a steep-walled depression which has a floor of several acres in extent. At the south end of this "gulf" the waters of Lost River well up in a deep, mud-lined, funnel-shaped pit. In high water periods the pit overflows, and muddy waters may cover the entire floor of the "gulf." Past floodings of the "gulf" have deeply alluviated the floor and given it a flat-bottomed aspect. The "gulf" never overflows, but the waters rising from the pit re-enter the subterranean channel through wood- and mud-clogged openings similar in character to swallow-holes. The Wesley Chapel "gulf" is perhaps the most spectacular topographic feature of the entire Lost River basin. The "gulf" is in the line of the direct course of subterranean Lost River.

It is at the Wesley Chapel "gulf" that the character of the subterranean conduit of Lost River may be observed for a short stretch. Entrance is gained through a small opening between the accumulated talus and the cliffed wall of the "gulf" on the west side near the south end of the "gulf." The opening leads down an inside talus slope with a low overhead roof of downward sloping limestone, which may once have been the roof of the subterranean channel. Immediately at the foot of the inside talus slope, some 40 feet below the opening, is the water of Lost River in its subterranean channel. In the dark quietness of the cavern the faint gurgle of the rippling eddies reaches the ear in a hollow, solemn monotone. The river here intruded upon ever courses on in its mysterious route. In flood times the cavern air is charged with a subdued rushing roar which comes from rapids and falls from some distance downstream. The water then reaches high up the inside talus slope, and here next to the water's edge gives forth but little more than a musical gurgle.

Perhaps as much as a thousand feet of the river cavern may be traversed. In places the water runs under low rock fluves, but higher side routes with clean-washed floors offer passage about the siphon-like water routes. Fallen blocks of rock are common, and they are being washed and dissolved away by the river waters which play about them. The walls of the cavern are angular-edged layers of raw limestone, practically free from travertine accumulations. By wading water of irregular depths, in places dangerously deep, one may pass down stream. The ceiling is low much of the way, but in places it is high and high-water routes pass about masses of fallen rock. Some 600 feet from the entrance the ceiling becomes low and the waters of the river descend through broken rock on the floor. Further passage appears to be barred. Upstream from the entrance passage is found partly through muddy side routes and partly in the irregular rocky floor of the stream for a

distance of perhaps 400 feet, where the water comes into the cavern river channel through masses of fallen rock. Everywhere the fallen rocks and the sidewalls are covered with a slimy mud which has settled out from the temporarily ponded flood waters of this part of the cavern.

This miserable little stretch of the underground river route gives us but a tantalizing glimpse of a mighty cavern, whose main channel length cannot be less than eight miles. Inadequate as it is, it is a sample of a big cavern in the making. Only at two or three other places may this great cavern be glimpsed, and at these places it is also ugly in roughness, slimy with mud filth, and coursed by a dangerous river. It presents a forbidding, mysterious, fearful picture to the senses, and it is impressive only when conceived as the underground conduit of a large stream more than eight miles in length and 60 to 150 feet beneath the upland surface which feeds water to it through ugly, nondescript inlets.

Marengo Cave has two outstanding characteristics which impress its visitors. These are its broad, even-floored channel course and its beautiful travertine decorations. I wish to speak chiefly of the former. For nearly half a mile Marengo Cave is essentially an underground channel which has been deserted by its former stream. It extends in a northwest by southeast direction with only such turns or bends as a surface channel of similar size would have. The floor of the cavern is 30 to 75 feet in width and is blanketed with a clay silt, in which is a channel 2 to 3 feet in depth and 10 to 20 feet in width. This channel swings from one side of the cavern floor to the other, somewhat as the channel of a surface stream in a narrow valley floor. Undercut places along the cavern walls are common. The channel bed in the clay silt has ripple marks, current-cut gouges, and spoon-shaped depressions of larger size, which clearly indicate the direction of flow of the stream that once occupied the cavern. The ceiling is 5 to 30 feet above the floor. Marengo Cave is a capacious cavern and is traversed with ease. Little or no fallen rock debris interrupt the channel floor. The only water in the cavern is that which seeps in from the roof, and this is chiefly confined to the two ends of the cavern where it is near the surface. The travertine formations of stalactite, stalagmite, and flowstone are very prolific in the two ends of the cavern where seepage is apparent. It appears that the carbonate growths, the features which both delight and amaze the visitor, have been formed chiefly since the cavern has been abandoned by the stream which once ran through it. Little other change has taken place. I would ascribe its channel preservation to the fact that the cavern is formed in rather massive beds of limestone. The cavern ceiling has a well developed arch in the massive strata, and there is little opportunity for rock collapse from the roof which would clog the channel floor. This condition was doubtless attained long before the stream, which largely formed the cavern, deserted it for a lower level.

Marengo Cave is a part of an underground route of a stream which once traversed it from the northwest to the southeast. It is near the

terminus of this former underground stream, and it probably yet connects with the surface valley swallow-holes about two miles north of the present cave. A large spring of greatly changing volume enters Whiskey Run Creek approximately at stream level about 300 yards west of the present cave entrance, which is near the upper or northwest end of the cavern. This large spring is an underground stream which issues from a cavern that is now being developed at a level some 20 to 25 feet below the abandoned stream floor of Marengo Cave. It is very likely that this stream still occupies an upper cut-off portion of the Marengo Cave system which has not yet been discovered. Whiskey Run, having been cut down to a lower level than formerly, offered opportunity for the underground tributary to seek a lower level. The underground stream has completely abandoned the lower part of its course, the present Marengo Cave, and now occupies a newer developing cavern channel from which it issues as a large spring.[1] Thus, Marengo Cave is a part of a subterranean conduit fully developed in rather massive beds of limestone—a cavern long deserted by the stream responsible for it, but which yet retains the characteristics of a water-made runway in an excellent state of preservation. In this great cavern runway have been formed the beautiful formations of stalactite, stalagmite, and flowstone, which astonish and delight the thousands of visitors who annually tread the smooth-floored channel of the former underground stream which left its tell-tale handiwork for those who may read its sculptural artcraft.

Wyandotte Cave is a complex cavern system developed at several levels. Its main galleries extend in a general north and south direction, and cross channels are present which, at a few irregular intervals, are found to connect the main galleries. There appear to be three main gallery-tiers or levels with, perhaps, one or two others of local or limited extent. The main galleries may be traversed for miles. Except in the little known and unexplored lowest level, water is nearly absent, and the dust of ages has collected upon the fallen blocks which litter parts of the cavern system. The lowest level may be conceived as one of the main levels, as it now carries the waters which have long ceased to run through any of the galleries composing the cavern system which is open to visitors. The existence of this water-coursed level is indicated chiefly by the occurrence of a large spring which issues southwest of the present entrance to the cavern system. This spring pours forth its considerable volume of water near the level of Blue River, which has an altitude of about 400 feet above the sea. The other main gallery levels are at altitudes of about 475 feet and 545 feet according to aneroid barometer measurements made by the writer fourteen years ago. The present entrance is at an altitude of about 575 feet, some 35 or 40 feet below the top of the limestone unit in which subterranean drainage is so well developed in southern Indiana and western Kentucky. The upland surfaces of the ridges between the deeply-set valleys are at

[1] See *A Preliminary Report Upon the Survey of Indiana Caves with Special Reference to Marengo Cave*, by Arch R. Addington, Eighth Ann. Rept., Indiana Dept. of Conservation, for 1926 (1927), pp. 21-31.

an altitude of 750 to 850 feet, and they are composed mainly of clastic rock strata. The Wyandotte cavern system lies wholly below an altitude of 610 feet, and at its maximum depths is nearly 400 feet beneath the sandstone ridge crests. I know little about the nearby valleys with their present swallow-holes and their disappearing streams, and I have no inkling of the sources of the streams which formerly ran through the galleries of the Wyandotte Cave system.

To the casual visitor Wyandotte Cave is a maze of passageways which connect both vertically and horizontally in a bewildering way. It is a labyrinth of galleries, rooms, and interconnecting passageways which leaves him in a helpless wonder. In a haze of bewilderment and wonder the cavern seems to be a succession of phenomena without order, system, or plan. But to the more frequent visitor who has become familiar with the phenomena of the cavern it does have order and system, and, aside from the beautiful chemically-deposited mineral accumulations which decorate parts of the cavern, two main characteristics stand out which give plan and comprehension to it. Parts of the cavern system are composed of relatively simple underground conduits, the floors of which are nearly level and covered with a yellow clay silt. These conduits occasionally have remarkably straight stretches of several hundred yards in length. They are simple, water-made runways which have been sculptured from the limestone strata by underground streams which have abandoned them, and as such they are little different from hundreds of other cavern runways developed in limestone strata as subterranean drainage lines. Other parts of the cavern system are in great contrast to the simple, dry channelways. Here the bottom of the cavern little resembles a floor. It is ruggedly uneven with masses of fallen rock which litter it or occur as great piles of slabby stone 20 to 60 feet or more in height. The great piles of rough rock rise up in expansive rooms which are commonly connected by narrow, nearly concealed passageways. In the part known as the "Old Cave" no less than seventeen hills of fallen rock 30 to 60 feet in height occur in a distance of a little over one-half mile. The thin, slabby rock composing these great hill-like piles has fallen from the roof of the cavern, and much of the rock which now composes the roof of this part of the cavern appears unstable and ready to fall; yet there is little evidence of recently collapsed rock masses. The rooms in which the hills of fallen rock occur rise with vaulted ceilings made of the rough edges of the relatively thin strata, culminating in a broad, overhead slab of unbroken rock which forms the smooth ceiling top of the rough vault below. The largest of the rooms is "Rothrock's Grand Cathedral," which is said to be 600 feet long and more than 200 feet wide. A mountainous mass of fallen rock, known as "Monument Mountain," capped with flowstone and stalagmites rises in the room 135 feet above the base and within 35 or 40 feet of the smooth stratum which forms the ceiling of the great vaulted room. The rock-littered, uneven floor, the mountainous piles of fallen rock, the expansive rooms with vaulted ceilings, and the narrow, difficult passageways at various levels and places are the distinctive features of this multi-galleried cavern. The simple, under-

ground river courses, for ages dry, characterize a part of the cavern system, it is true; but they are little distinctive and much less impressive.

Often I look at the distinctive features of the Wyandotte cavern system and am reminded again and again that it is a cavern in ruins. Throughout a goodly part of the system its river channel characteristics are gone, and little remains to remind one of the waterways which once were magnificently present. The fallen-in condition is probably partly dependent upon the development of the younger galleries beneath the older ones, but it appears that the great rooms with their mountainous piles of fallen rock are chiefly due to the much fractured, thin-bedded strata, which, undermined in the making of the runway voids, have collapsed in weakened localities to make the vaulted rooms and the piles of slabby rock which give the cavern its most distinguished characteristics.

The three cavern pictures here attempted are based upon selected observed phenomena of three particular caverns. Comparisons are inevitable. One cavern is in vigorous youth. It is magnificent in certain of its outlines, but is yet unfinished and ugly. It is occupied by a mysterious and dangerous underground river. Another cavern is in full maturity. It is grandly made and beautiful in its finished and fully completed form. It is truly a great runway cavern whose chief characteristics clearly indicate the work of an underground river which now does not occupy the course it fashioned. The third is a complex cavern system which is undergoing a grand and admirable degeneration. Its distinctive characteristics are the magnificent ruins of a grand series of underground conduits which now show little of their former features as completed, water-made runways. Parts of this cavern system certainly present old age aspects in cavern history.

THE HISTORY OF THE "HOODOOS" NEAR MAMMOTH HOT SPRINGS, WYOMING.

By ALLEN D. HOLE, Earlham College.

The area here referred to, known popularly as the "Hoodoos," is located in Yellowstone National Park about two miles in a southerly direction from Mammoth Hot Springs. It is crossed by the main north-south road leading southward to Norris Geyser Basin, and is therefore familiar in a general way to all who have visited the Park.*

The most striking characteristic of this area, as an observer first views it, is its exceedingly rough and apparently chaotic nature. Huge, angular blocks of stone, varying in size up to 30 or 40 feet in diameter, lie tilted at various angles, and the confused effect is heightened by the fact that the road winds about in a most irregular manner in order to find a possible path across the forbidding surface (see fig. 1). To one who remains on the road the general relations existing between the Hoodoos and the surrounding topographic features are effectually concealed; but to one who climbs to the top of Terrace Mountain, or well up on the slope of Bunsen Peak, the area appears strikingly different, partly because the details of its surface no longer obscure its general features, and partly because the relations of the area to the adjacent slopes, cliffs, and mountains can then be seen.

As seen from an elevation sufficient to permit a general view, the area called the Hoodoos appears somewhat like a relatively broad, slightly winding stream of rock fragments extending from near the base of a portion of the nearly perpendicular cliff face which forms the eastern face of Terrace Mountain in a general southeasterly direction across the road and on down the valley slope practically to the waters of Glen Creek. The particular portion of the cliff face on Terrace Mountain lying directly above this rock stream bears about north 45° east, thus facing southeastwardly. This portion of the face is, measured along its edge, about one-fourth of a mile in length, and the rock stream below has a width which is, on the average, approximately the same. The length of the area, which is here likened to a rock stream,

* The area here called the "Hoodoos" is not to be confused with another region, on the east side of the Park in the Absaroka Range of mountains which has also been called the "Hoodocs," but which is an entirely different region and different not only geographically but historically from the Hoodoos south of Mammoth Hot Springs.

Note: The account here given is based upon observations made by the author and by students under his direction, enrolled as members of classes in the Department of Geology in Earlham College. These observations were made in the summers of 1923, 1925, 1926, and 1928, as a part of a program of systematic geological field work. Acknowledgment is here made of assistance rendered to these field parties through privileges granted by Superintendent Albright, and practical interest in the work shown by rangers and other Park officials.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

measured from near the base of the cliff face on the southeastern side of Terrace Mountain to its end near Glen Creek, is about five-eighths of a mile. The average steepness of the slope of the surface of the area, measured along its length from the cliff face on Terrace Mountain to Glen Creek, is about 12°; the upper portion of the area, that is from the cliff face down to the road, is steeper than this average, being approximately 20°, while the slope below the road to Glen Creek averages less than 12°. The difference in elevation between the upper and lower ends of this rock stream is about 700 feet.

Fig. 1. View along road near Silver Gate, in the Hoodoo region; looking in a northeasterly direction. Note the stratification lines of the large blocks dipping in most cases to the left, that is, is a northwesterly direction. (Photo by Joseph Borden.)

DETAILED DESCRIPTION.

In addition to the general characteristics and relations enumerated above, the following details deserve attention as being more or less essential to an understanding of the history of the area, viz.:

1. When viewed from some distance the generally inclined surface of the area is seen to be characterized by more or less distinctly marked ridges which are, in general, approximately parallel to the cliff face on Terrace Mountain near which the upper end of the rock stream lies. Instead of being precisely straight, however, these ridges tend to be slightly concave in a northwesterly direction; or, stated in another way, they are slightly convex toward Glen Creek as if their central portions had moved a little farther than their ends. Furthermore, the ridges are, in general, straighter and more distinct near the cliff face than farther from it. The first ridge, the one nearest the cliff face, is well marked for a part of its course. Farther away from the cliff face, in that portion of the area in which the largest blocks of rock are found, the ridges are not perceptible except when the surface is viewed from a distant point.

2. The rock represented in the angular fragments observable on the surface of the area is chiefly travertine, precisely similar to the travertine forming almost the whole of the cliff faces on Terrace Mountain. In addition to the travertine, however, there are found scattered irregularly here and there throughout the area boulders, gravel and rock fragments of a variety of kinds, including limestones, sandstones, quartzites, and shales indistinguishable from the rocks constituting the Paleozoic formations outcropping in the Gallatin Mountains, together with a variety of igneous and metamorphic rocks, such as gneiss, schist, granite, andesite, dacite, basalt, and obsidian. These metamorphic and igneous rocks are identical in kind with outcrops in the Gallatin Mountains and other points situated in the direction from which glacial ice of the last epoch came—identical also with the kinds of rock found on top of Terrace Mountain which have been interpreted as evidence that the ice sheet (or ice sheets) of the last glacial epoch passed over Terrace Mountain from the west, southwest, and northwest into that portion of the valley of Glen Creek lying north of Bunsen Peak and east of Terrace Mountain, moving thence northeastwardly to join the glacier which moved down the valley of Gardiner River.

3. In that portion of the area in which the largest blocks of travertine are found the spaces between the blocks are especially large, the openings in some cases seeming to lead downward as if to the entrance of caverns. A number of these openings were explored, especial care being taken to make note of any signs which might be interpreted as evidence of formations characteristic of caverns, such as stalactites, stalagmites and sheet incrustations of calcite. Not only were no such formations observed, but it was also noted that the openings entered had in all cases merely the irregular shapes which result when large blocks of rock are heaped together. In general these openings extend but a short distance. One, however, which it seemed could not be entered except by use of a rope let down into it from above, was found to end abruptly in a dark, angular, enclosed space occupied by bears. Needless to say, exploration in that particular direction was promptly abandoned. Examination of these openings was prosecuted with sufficient thoroughness, however, to warrant the conclusion that not only are there now no caverns in that area due primarily to the work of solution by underground waters, but that the fragments of rock forming the surface of the area have not in general formed parts of walls of such caverns in the past.

4. In the search for data in the field which would be of significance in reading the history of the area it finally seemed clear that a test should be made to determine, if possible, whether the arrangement of the large blocks, as shown by their average direction of dip, is in reality so entirely chaotic and lacking in order as a first glance at the surface suggests. It was therefore determined to record accurately the amount and direction of dip of as nearly all blocks above 20 to 25 feet in diameter as could be examined in the time available. This plan was followed in each of four field seasons, with the result shown in Table I. The measurements listed and collected on the graphic circular diagram,

figure 2, include all measurements made by two separate groups of observers. The total number of observations made is far in excess of those here recorded, but the prevailing trend when all are taken into account is essentially the same as shown here. The smaller number, representing as it does the essential relations observable in the total, is chosen for presentation chiefly because a diagram with a larger number of lines would be more confused and therefore less clear.

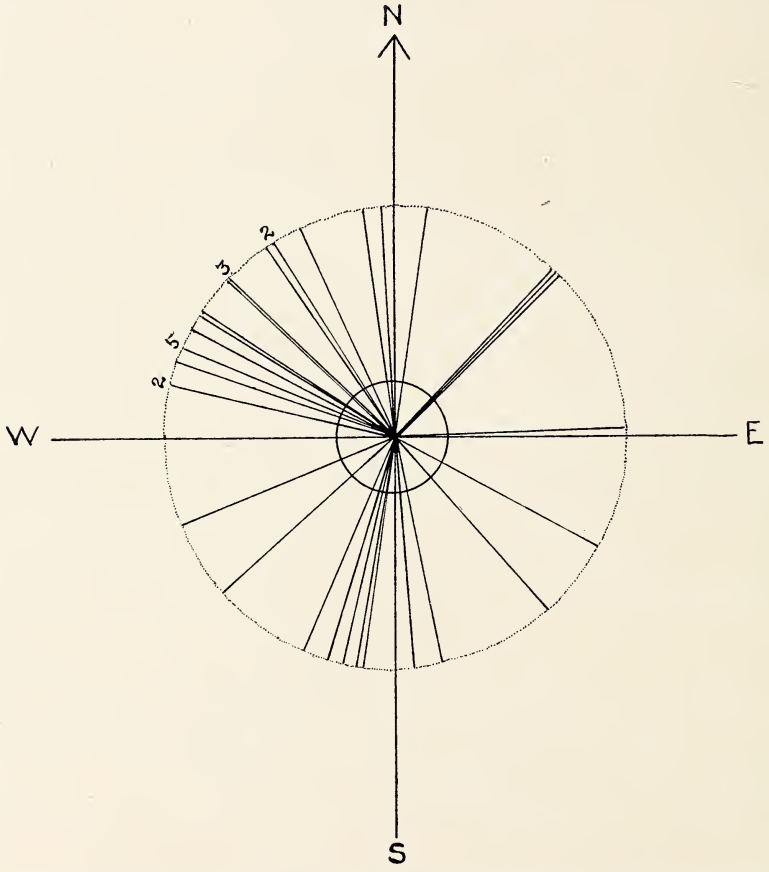

Fig. 2. Diagram showing directions of dip of the 37 blocks listed in the accompanying table. The numbers opposite certain lines in the northwest quadrant indicate the number of blocks having the same measured direction of dip; for example, the line N. 67° W. represents five separate blocks, each having the direction of dip N. 67° W. All other lines in the respective quadrants represent dips of single, separate blocks.

TABLE I. Showing measured degree of dip and direction of dip of 37 blocks 20 feet or over in diameter, selected at random.

Degree of Dip.	*Direction of Dip.*
71°	N. 44° E.
35°	N. 43° E.
43°	N. 3° W.
50°	N. 24° W.
29°	N. 46° W.
69°	N. 58° W.
47°	S. 10° W.
36°	N. 46° W.
44°	N. 34° W.
47°	N. 67° W.
41°	N. 71° W.
41°	N. 46° W.
64°	S. 4° E.
62°	N. 8° W.
33°	N. 46° E.
60°	N. 47° W.
30°	N. 67° W.
25°	N. 62° W.
30°	N. 57° W.
15°	N. 88° E.
70°	N. 8° E.
35°	N. 32° W.
20°	N. 67° W.
65°	S. 48° W.
25°	S. 12° E.
70°	N. 32° W.
65°	S. 42° E.
45°	S. 62° E.
60°	N. 77° W.
40°	N. 67° W.
30°	S. 68° W.
55°	S. 13° W.
25°	N. 77° W.
65°	S. 8° W.
40°	S. 17° W.
35°	N. 67° W.
25°	S. 23° W.

An analysis of the measurements recorded in Table I or an inspection of the diagram, Figure 2, shows that of the 37 blocks of travertine, whose dip and direction of dip are here recorded, more than 75% dip in a westerly direction; and of these 28 blocks which dip in a westerly direction 21, or 75% of the 28, dip in a northwesterly direction. In tabular form the measurements recorded may be classified as follows:

TABLE II.

	Number of Blocks.	*Percentage.*
Dipping westerly	28	75.67
Dipping easterly	9	24.32
Totals	37	99.99
Dipping northwesterly	21	56.75
Dipping southwesterly	7	18.91
Dipping northeasterly	5	13.51
Dipping southeasterly	4	10.81
Totals	37	99.98

SIGNIFICANCE OF DIRECTION OF DIP.

Of the various theoretically possible classifications of direction of dip of large fragments of rock lying below a parent cliff face, observation shows that only two are of practical importance, namely:

1. Situations in which the dip of strata in the rock fragments is essentially without any system; and

2. Situations in which there is a notable predominance of dip toward or approximately toward the parent cliff face.

The causes and conditions determining these two classes of situations seem to be:

1. Changes of temperature, wedge work of roots of trees, undercutting of a cliff, or some such process, in such manner and to such a degree as to cause the rock fragments to fall outward from the cliff face and to come to rest after rolling partially or entirely over. In other words, rock fragments found lying without any systematic or prevailing direction of dip are essentially talus slopes which have accumulated under conditions permitting more or less free fall outward from the cliff face. Figure 3 shows such rock fragments in size up to 30 feet in maximum diameter, lying on a slope of rock waste derived from a cliff of Ordovician limestone in the Bighorn Mountains, Wyoming. The different directions of dip represented by these large rock fragments are in general as numerous as the number of the fragments observed.

2. If, on the other hand, the method by which the large rock fragments are separated from the parent cliff face is predominantly that of failure of support, as is the case where the rock formation in question rests upon a clayey or shaly base, which is at times weakened by being more or less completely saturated with water, then the majority of the large fragments do not have opportunity to fall outward from the cliff face, but settle down and slide away at a rate determined by various factors, such as: (1) the degree of weakening due to partial or complete saturation with water of the underlying stratum, (2) steepness of the slope previously developed, (3) size of fragments of rock as determined by jointing, etc. If the migration of rock fragments from the parent cliff face follows this general method, observation shows that the blocks of rock tend to rotate on axes approximately parallel to the

Fig. 3. Large fragments of Ordovician limestone and cliff from which they were derived. Location, seven miles northeast of Hazelton, Wyoming, near east front of the Bighorn Mountains. The underlying formation here does not favor landsliding as the primary method of movement of rock fragments. (Photo by the author.)

parent cliff face so as to become tilted backward toward the cliff face as they move away by slipping and sliding on a yielding stratum or medium beneath them. This fact has long been recognized by geological observers. Russell, for example, records the results of his own observations in such cases.* Figure 4 is adapted from an illustration used by him in the article referred to, on page 487. Figure 5, reproducing a photograph of a landslide block in the San Juan Mountains in Colorado, illustrates the same fact, namely, that large blocks of rock, moving down

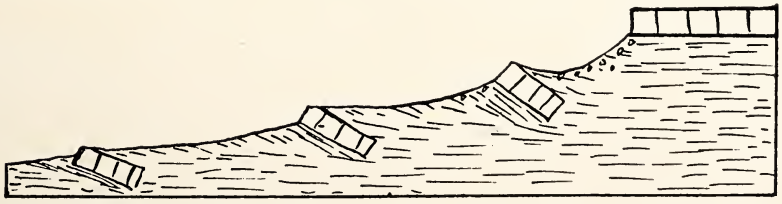

Fig. 4. Diagram, after Russell, illustrating the typical backward dip of blocks which, on breaking off, have been carried down by sliding on and with yielding material, such as water-soaked shale or clay.

* Russell, I. C., Topographic Features due to Landslides; Pop. Sci. Mo. vol. 53, pp. 480-489, August, 1898.

a slope from a parent cliff face by failure of an underlying stratum, tend to become inclined backward toward the face of the cliff from which they came.

With the establishment of the fact that the number of large blocks having a pronounced dip toward the cliff face on Terrace Mountain is proportionately large, and with the principles in mind which have just been explained, the conclusion follows that this area known as the Hoodoos owes its origin primarily to the breaking off of large fragments of travertine from a succession of cliff faces similar to that now forming the eastern side of Terrace Mountain, and the transportation of most of these blocks toward Glen Creek by the process of landsliding.

Fig. 5. A landslide block of Potosi rhyolite, situated two and one-half miles south of east from Trout Lake, Telluride Quadrangle, Colorado. View looking north from a distance of one-half mile. Note dip back toward steep ridge, 1000 feet higher, from which this tilted block came by slumping or sliding. (Photo by the author.)

HISTORY OF THE REGION.

The principal events recorded in the region under consideration are included in these three series, viz.:

1. The formation of the travertine which now makes up the upper portion of Terrace Mountain.

2. The glacial action which has been responsible for the transportation to this area of the boulders, gravel, and other material from the Gallatin Mountains and other points to the west, southwest, and northwest of Terrace Mountain.

3. The partial disintegration of the mass of travertine, the remnant of which now forms the top of Terrace Mountain, and the distribution of a considerable proportion of the rock fragments thus derived over the eastward and southeastward-facing slope of the valley of Glen Creek.

Not only are the chief events recorded in this region included in the three series named above, but the order in which these three series of events occurred must have been, in the main, the order which has just been stated. The principal reasons for interpreting these events as occurring in this order are the following:

1. The glacial boulders, gravel, etc., found now on the top of Terrace Mountain prove that the travertine forming that mountain was deposited before the last period of glaciation in that region.

2. The huge, angular blocks of travertine forming the characteristic feature of the Hoodoo area, together with the many small angular blocks which in many places accompany them prove that the glaciers passed over Terrace Mountain before the present Hoodoos were in existence.

3. The occasional glacial boulders, gravel, etc., found today scattered here and there among the blocks of travertine forming the area known as the Hoodoos, indicate that both the travertine blocks and the glacial material which lie together in the Hoodoos were derived from an eastward extension of Terrace Mountain which has disintegrated since the disappearance of the last of the recent glaciers. The present Hoodoos are made up, therefore, of the products of such a disintegration.

SOME FURTHER QUESTIONS.

Although the general outline of the history of the area known as the Hoodoos is thus clearly established, some questions which are in the nature of detail, yet of interest and importance historically, cannot as yet be answered with certainty. The most outstanding of these questions are:

1. Of what is the yielding stratum composed upon which the disintegrated travertine forming the Hoodoos has moved by sliding and slipping to its present position?

2. How far to the eastward from the present cliff face on Terrace Mountain did the mass of travertine originally extend?

3. Is the presence of true morainal topography to the northward and northeastward of the Hoodoos due in part, possibly chiefly, to a difference in the character of the geological formation which lies a short distance below the surface there? May it be due in part to a reduction, in that section of the valley, of the amount of travertine available for disintegration?

SUMMARY.

The area known as the Hoodoos, situated about two miles south of Mammoth Hot Springs, in Yellowstone National Park, Wyoming, while marked by the presence of numerous large angular blocks of travertine lying in apparent confusion, is found to possess certain definite characteristics which, when they are considered in rela-

tion to each other, afford proof of the cooperative action of a series of geological agencies which have been responsible for the result seen in this area today. Chief among these characteristics are the following:

1. The stream-like character of the area as a whole extending from the perpendicular cliff face on Terrace Mountain eastwardly and southeastwardly to Glen Creek.

2. The presence on the surface of this stream-like area of a series of more or less clearly marked ridges extending, in general, approximately parallel to the cliff face on Terrace Mountain.

3. The fact, determined by careful measurement, that the predominant direction of dip of the stratification planes of the large rock fragments is backward at a notable angle toward the west and northwest, that is, toward the parent cliff face from which the blocks of rock came.

The conclusion from these facts and from the general field relations involved is that the area known as the Hoodoos has resulted from the transportation of loosened blocks of travertine from their original location as an extension of the mass of travertine forming the upper portion of Terrace Mountain, chiefly by the process known as landsliding.

CONTRASTS AMONG INDIANA COUNTIES IN THEIR YIELD OF PROMINENT PERSONS.

STEPHEN S. VISHER, Indiana University.

I. HOOSIERS SKETCHED IN "WHO'S WHO."

In *Who's Who in America*, vol. 14, 1926-1927, there are sketches of 913 persons who gave their birthplace as Indiana. All but one of these persons indicated, by county or town, where their birthplace was located.

The distribution of the birthplaces of these 912 Hoosiers has been studied in various ways, in an effort to learn more concerning the conditions conducive to the production of leaders.

In respect to the center of the state's population in 1870, 522 were born south of the latitude of the center of population and 388 north, 513 were born east of the longitude and 397 west. The southeast quarter of the state's population produced 301, the southwest 221, the northeast 212, and the northwest 176. Hence the southeast quarter did nearly half again as well as the northeast or southwest and not far from twice as well as the northwest quarter.

In proportion to population at the 1870 census, the geographic region "Northern Indiana" produced one notable for each 2,330 persons, "Central Indiana" one for each 1,500, and "Southern Indiana" one for each 2,120.

Within the diverse region, "Southern Indiana" there is considerable contrast. The unglaciated south-central area did poorest, yielding one notable for each 2,280 persons at the 1870 census on the average. The area west of it yielded one for each 2,120 and the area to the east one for each 1,770 persons on the average. Within unglaciated Indiana, three subdivisions are recognized: the limestone belt or "Mitchell Plain," with a productivity of one notable for each 2,000 people; the "Crawford Upland," a rather rugged belt just west of the limestone belt, which yielded one notable for each 2,400 people; and, finally, the "Norman Upland," just east of the limestone belt, which yielded one notable per 2,670 people. The southeastern portion of the state also has three subdivisions, of which the one farthest east, next to Ohio, did best, yielding one notable per 1,570 people, in contrast with one per 1,960 in the next and one per 1,900 in the "Scottsburg Lowland."

The nine most populous counties of Indiana in 1870 yielded 257 of the 912 notables or at the rate of one per 1,290 people. This is an appreciably higher rate than that in the best geographic region, "Central Indiana" (one per 1,500). However, there were ten counties which yielded more notables in proportion to population than did the nine most populous counties, on the average. This was despite the fact that the best county of the state, Wayne, with a record of one notable per each 800 people, was one of the most populous ones. The best counties and the thousands of people at the 1870 census per notable were, in order, Wayne (.8); Johnson (.9); Scott (.9); Putnam (1); Jasper (1.1); Montgomery, Hendricks, Marion, Switzerland, Monroe

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

(1.2); Carroll, Whitley, Dearborn (1.3). Figure 1 gives for all the counties the number of 1,000 people at the 1870 census per notable born in that county.

Yield of Cities and Towns. Slightly more than half of the *Who's Who* notables born in Indiana were born in county seats; 466 out of 912. The combined population of the county seats in 1870 was 466,000, or 27 per cent of the state's population. In other words, the county seats yielded notables at nearly three times the rate, in proportion to population, that the rest of the population did. The county seats of the central part of the state did best, yielding a notable per 514 people, on the average. The county seats of "Northern Indiana" averaged one notable per 680 persons and those of "Southern Indiana" one per 700 persons. In respect to the subdivisions of "Northern Indiana," the northeast, Lake and Morainal sub-region, with one notable per 620 people, did notably better than the northwestern, Kankakee sub-region, with one per 960 people. Among the subdivisions of "Southern Indiana," the county seats of the Wabash Lowland yielded one notable per 800 people, the unglaciated section one per 620 people, and the southeastern section also one per 620 people.

While for the average of the state, the 27 per cent of the people living in the county seats yielded as many notables as the 73 per cent of the population living elsewhere in the county, the proportion born in the county seats was much greater in many of the counties of southern Indiana. For example, all of Washington County's 5 notables were born in Salem, all of Vanderburgh's 21 were born in Evansville, 10 of Monroe County's 12 were born in Bloomington, 7 of Knox County's 8 were born in Vincennes. The ratio between the county seat and the rest of the county in certain other counties is as follows: Spencer 4 to 1, Posey 5 to 3, Floyd 12 to 1, Ohio 3 to 1, Union 3 to none, Vigo 17 to 5, Clark 5 to 2.

The section of the state where the population outside of the county seats did best, relatively, in producing notables was the east central and northeast. The people outside of the county seats were about half as productive, in proportion to population, as were those of the county seats, in several of these counties, and in a number of them the county seat was relatively unproductive. But in most such cases the county seat was an insignificant place.

In nearly all of the counties of Indiana the largest city in 1870 was the county seat, but there was an interesting exception. In Clark County, Jeffersonville, the present county seat, was then much larger than Charlestown, then county seat (population 8,000 vs. 2,200), but Jeffersonville yielded no notable while Charlestown yielded five. Jeffersonville contained the state prison; it was also more industrial and less pleasantly located than Charlestown.

Comparison has been made of the productivity of the larger cities of the three regions. The 11 cities of "Northern Indiana" having a population of 2,000 or more in 1870 yielded 72 notables, or one per 750. The 13 such cities in "Central Indiana" yielded one notable per 670 people while the 14 such cities of "Southern Indiana" yielded one per 970 people. The average for the cities of the state was one notable per 780

people. Cities of 2,000 or more population in 1870 which did especially well in their yield of notables, in proportion to population, are as follows: Crawfordsville, Franklin, Greencastle, Muncie, Richmond, Shelbyville (each one notable per 300 to 400 population); Cambridge City, Charlestown, Columbus, Kendallville, Lawrenceburg, and South Bend (each one notable per 400 to 500 people.)

Comparison with the yield from all county seats reveals the interesting fact that in all three regions the cities of over 2,000 population did less well than did the county seats. As the larger cities were practically all county seats, it follows that the smaller county cities did notably better in the production of these notables in proportion to population than did the larger cities.

Comparison between the group "all cities over 2,000 in 1870" with the group "the cities with 8,000 population or more in 1870" reveals the fact that these ten largest cities yielded notables at the rate of one per 905 people, on the average. In other words, the largest ten cities yielded notables at only about four-fifths the rate of the next 28 cities in size, and only about two-thirds the rate of the smaller county seats, on the average.

The nine college towns of Indiana in 1870 (Indianapolis being omitted) yielded notables at the average rate of one per 530 people, almost twice as many as did the 10 largest towns without colleges in 1870, which had a ratio of one per 1,100.

Among the county seats, Paoli, yielded most notables in proportion to population, 6 notables per 600 population, or one per 100. The county history states that two-thirds of the early settlers were Quakers. The Lindleys, progenitors of Chancellor Lindley, of the University of Kansas, were the first settlers.

The 12 notables yielded by Bloomington, were descended almost wholly from a small group of Scotch-Irish Presbyterians who settled there at an early date, and retained and nurtured the State University.

The excellent showing of Richmond and other parts of Wayne County is related to the large Quaker element in the population and in numerous high-class English emigrants.

Comparisons with other conditions. Comparisons have been made between the maps showing the county contrasts in productivity of notables and various other maps. The Census Bureau maps of density of population 1840-1890 afforded some suggestive correspondences. The densest group of counties in 1840 (extending from Wayne to Floyd) nearly all produced many notables, except Ripley, but part of the least dense counties also did well. The area of the Miami Indian Reservation has done poorly.

In 1870 the northern part of the state which was especially dense in population was that between Michigan City and Indianapolis, in which area fewer notables have been produced, in proportion to population, than in the areas to the east or west.

In 1880 the unglaciated area of the state first stands out conspiciously as being less densely populated than adjacent areas. Except Bloomington, Paoli, and Salem, this unglaciated region has done poorly in producing notables.

In 1890 the areas just east of the unglaciated area fell to a similar density of population. Except for Scott county, this area has done relatively poor in yielding notables.

In brief, a comparison between the maps of density of population and of the yield of notables in proportion to population discloses no close relationship, altho there are suggestions that areas of comparatively sparse population are somewhat less favorable to the production of notables than are adjacent counties which are somewhat more densely populated. However, there are so many local exceptions to this generalization that it receives little support from the evidence here available. Density of population as such appears to be far less significant than concentration of population (urbanization). Although many densely settled rural counties yielded more notables in proportion to population than did neighboring less densely settled rural counties, nevertheless they did less well than most nearby counties which possessed an attractive town or city, in spite of a smaller total population.

The great importance of mothers of notables and of women teachers of notables has often been commented on. It has also been noticed by R. M. Harper that certain areas in Georgia in which women predominated in the population produced more notable men than areas in which men predominated. Thus it is not entirely surprising, but nevertheless is very interesting, to note the complete agreement between the Indiana county map of production of notables (fig. 1) in proportion to population and the census map which shows the sex ratios for 1900. All of the counties in which women and girls were more numerous than men and boys did conspiciously well in producing notables. As such counties are characteristically those from which there has been an emigration of men, it is not surprising to note that all of the Indiana counties, except Brown County, which lost population between 1890 and 1900 did well in the production of notables. But during the next decade many counties which did poorly in yielding notables lost population. Hence, it follows that the counties which most quickly responded to unsatisfactory agricultural conditions and most promptly sent many men to the cities were those who produced relatively many leaders. This prompt response is in accord with other evidence of the superior alertness and mobility of the parents of notables. They are quick to see unsatisfactory conditions and soon afterwards are on the outlook for opportunities to better their lot.

There is no obvious relationship between the distribution of foreign-born in Indiana in 1870 and the production of notables, partly because there were relatively few foreign-born here then.

The map of illiteracy in 1900 is, in general, the converse of the map of yield of notables (fig. 1).

The census map of 1900 showing the average size of family is also closely comparable with figure 1. The counties with the smaller average families did better than the counties with the largest average families, without exception. This condition also suggests alertness on the part of communities which yield notables in adopting new methods and higher standards of living.

The eight poorest counties on the 1900 map of per acre value of

farm products all did poorly in yielding notables. Also, counties which did poorer than their neighbors in producing crops produced fewer notables except Randolph and Hancock.

Similarly, the counties with a low per square mile production of farm products did relatively poorly. This was conspiciously true of Starke and Pulaski counties, which yielded no notables, and of Ripley, and of all of the counties of the unglaciated area except Monroe County.

None of the counties producing relatively few notables did much manufacturing in 1900, when manufacturing was first becoming important in Indiana. All of the counties producing manufactures worth over $25,000 per square mile produced a fair share of notables, but only Wayne and Marion counties were among the state's leaders in regard to both manufacturing and notables in proportion to population.

Maps showing the ratio between commitments (for the average of 1918-1927) to the three state penal institutions in proportion to population (figs. 2, 3, and 4) have been compared with figure 1, the yield in notables in proportion to population. The counties of the Wabash Valley stand low (unfavorable) on all four maps, while most of the counties of north central Indiana stand relatively high (favorable), as do most of the counties at the southeast corner. However, several counties in south-central Indiana which yielded relatively many notables also send relatively many prisoners to the state prison, penitentiary, and penal farm. Possibly this merely indicates a higher degree of law enforcement.

Comparisons Between County Yield of Notables and of Indiana University Graduates: The distribution of *Who's Who* notables born in Indiana may advantageously be compared with the distribution of graduates of Indiana University, since both groups differ from the general population in possessing greater ambition, intellectual alertness, persistence, and social mobility. Therefore, data as to recent graduates supplement and strengthen the findings as to *Who's Who* notables. For the ten years 1918-1927, the graduates from each county, each county seat, from other cities, and from elsewhere in the county have been tabulated. Separate record has also been made as to those graduating with honors.

In the ratio coming from the county seats, the situation is closely similar in respect to both the *Who's Who* notables and the students who graduate. About two-thirds of the students come from the county seats, which had in 1920 a combined population of only about one-third of the state's population. Furthermore, the ratio from the county seats is greater in most of the counties with small county seats than from those with large ones. The proportion from the county seats is larger in "Southern Indiana" than in "Central or Northern Indiana," but smallest in northeastern Indiana, just as it was in respect to notables.

Of the students graduating, the largest percentage (4.8 per cent) graduating with honors came from northern Indiana. Central Indiana came next, with 4.3 per cent, and southern Indiana stood lowest with 3.1 per cent, or if Bloomington, in which the University is located, be excluded, with 2.7 per cent. This is not simply a matter of selection of distance, as the proportions of the population of "Northern" and

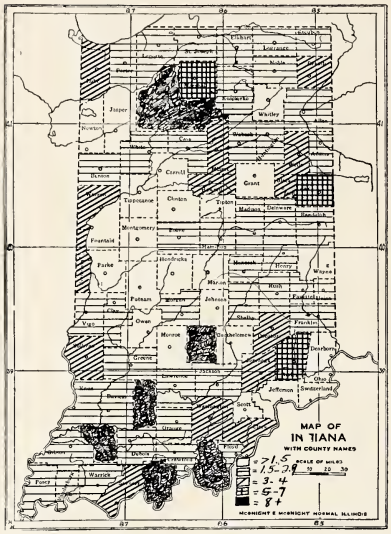

Fig. 1—Number of 1,000 persons in 1870 per notable sketched in *Who's Who in America*, vol. 14, who gave his birthplace in these counties.

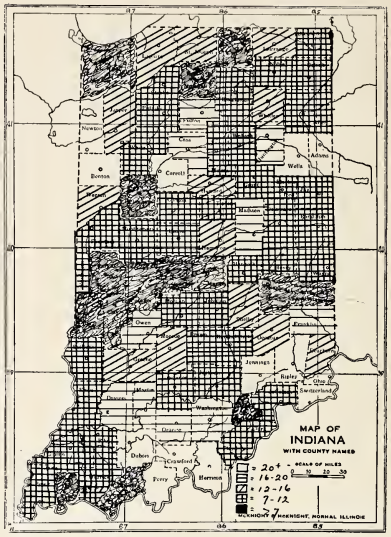

Fig. 2—Commitments to the State Prison (annual average 1918-1927) in proportion to population. Figures are 1,000 people at 1920 census in each county per person committed to State Prison.

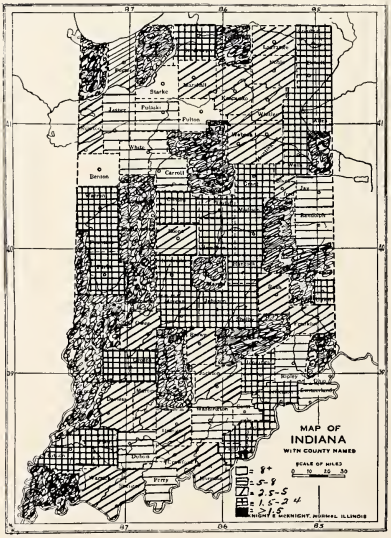

Fig. 3—County representation of annual admittance at the State Penal Farm, average 1918-1927. Figures are 1,000 of people in the county per prisoner at the State Penal Farm from that county.

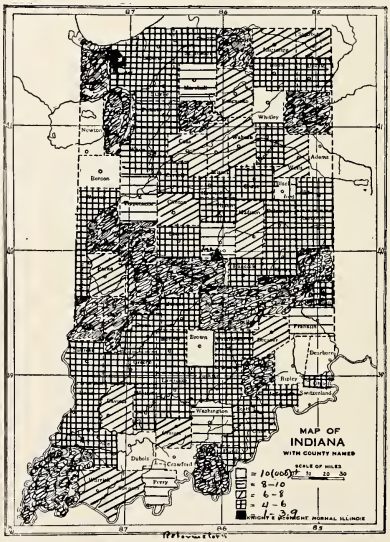

Fig. 4—Admittances to the State Reformatory Oct. 1, 1917 to Sept. 30, 1927. Number of 1,000 persons in county at 1920 census per prisoner sent to Reformatory, average year.

"Central Indiana" attending Indiana University is larger than that of most of "Southern Indiana" except Monroe County and its immediate vicinity.

Thus the data on the percentage of the students from each of the counties and towns graduating at Indiana University in the decade 1918-1927 and the percentage receiving honors shows significant correspondence with the data as to notables. In each case the county seats did conspiciously well, and the smaller county seats better in proportion to population than the largest ones. Also south-central and southwestern Indiana did relatively poorly in both regards, except Bloomington. Also northeastern Indiana did conspiciously better than northwestern. However, southeastern Indiana did less conspiciously well in respect to students than it did in respect to notables. But Bloomington has been until very recently comparatively inaccessible from southeastern Indiana, with the result that many of the students from that section have attended other institutions. Furthermore, it is likely that, accompanying the decrease in population since 1870, there has been an emigration from southeastern Indiana of enough capable people to reduce the percentage of superior people in the population. This hypothesis is supported also by the evidence as to insanity, it will be recalled, as well as by considerable biographical data.

II. INDIANA WOMEN SKETCHED IN WHO'S WHO.

Indiana was the native state of 47 women sketched in volume 12 of *Who's Who*. They were born in 28 of the 92 counties. Three counties yielded 13 persons: Marion five, Vigo four, and Morgan four. None of the 47 were born in the 17 unglaciated counties of southern Indiana, which region, according to its population in 1870, should have contributed seven. The portion covered by the Illinoian glacier, but not by the Wisconsin, yielded only 9, which is only about one-half its proportion. The southwestern part of the state produced only 4, 3 of whom were born in or near Evansville. The northern half of the state, north of the latitude of the center of the state's population in 1870, produced one-third of the 47. The triangular area extending southeast from near the center of the state yielded 20 of the 47. Out of the 47, only 17 attended Indiana colleges, only 6 receiving B.A. degrees and 3 doing graduate work.

III. STARRED SCIENTISTS.

Fifty living, or recently living scientists, starred by the vote of their fellow scientists in Cattell's American Men of Science, 1906, 1910, 1921, or 1927, were born in Indiana, coming from 33 counties. (Fig. 5.) Six counties produced 3 each and 6 others 2 each. Their distribution in respect to the center of population in 1870 is as follows: north of latitude of center 14; south of same 36; east of longitude of center 33; west of same 17; northeast quarter 9, northwest quarter 6, southeast quarter 25, southwest quarter 11. The unglaciated region, one-fifth of the state with fully one-fifth of the population in 1870, produced 9 of the 50 or less than one-half of its due proportion, although it contains Indiana University. The numerous well populated counties of the Wabash Lowland in the southwestern part of the state produced none.

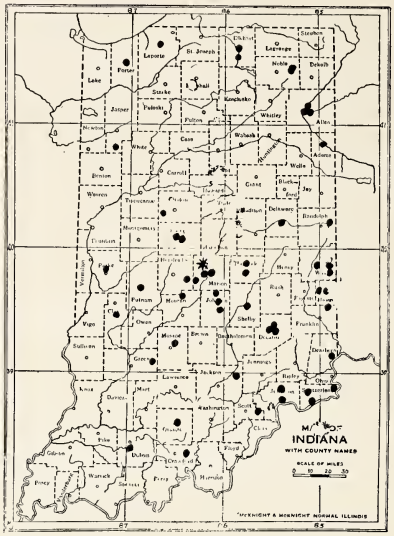

Fig. 5—Birthplaces of the 50 starred Scientists born in Indiana.

The many towns and counties along the middle and upper Wabash were almost equally sterile as were the counties along the lower Ohio River, below Madison. The southwestern unproductive area is contiguous to a similarly unproductive area in southeastern Illinois and in western Kentucky. These regions were settled early chiefly by people from Kentucky or other southern states. People with southern ancestry spread northward up the Wabash during the years of canal construction. In contrast with the unproductiveness of the southwestern counties is the fine showing of most of the southeastern counties. Thirteen starred scientists were born in Marion and adjacent counties in the fertile central part of the state, 6 in the Quaker community near Richmond, and 7 in the extreme southeastern corner of the state near Cincinnati. These southeastern counties were settled about as early as the southwestern counties, but more largely by people from Ohio, New York, Pennsylvania, and New England. The relative unproductivity of the northern half of the state appears related to its later settlement, in a large part by newly arrived immigrants from Germany or Ireland and by the northward spread of the people from southwestern counties. The great migration from New England gave Indiana few settlers, because of geographic conditions. However, 3 of the 4 Hoosiers first starred in 1927 were born in northeastern Indiana (Adams, Allen, Elkhart counties), and the fourth in southeastern Indiana (Franklin County).

In respect to towns, seven of the 50 scientists gave their birthplace by counties, and presumably were born on farms. Only 2 were born in Indianapolis, which was a city of 48,000 in 1870. None were born in the then Indiana's second largest city (Evansville) or the fourth (Terre Haute). Three were born in Fort Wayne and 2 each in Richmond and Greensburg.

SOME FEATURES OF THE UPPER SURFACE OF THE TRENTON LIMESTONE IN INDIANA.

WILLIAM N. LOGAN, Indiana University.

Prominent features of the upper surface of the Trenton limestone in Indiana as revealed by well logs and by the study of drillings was presented by the writer in a publication[1] issued in 1920. In the map prepared and published in that report the position of the upper surface of the Trenton was indicated by contour lines which were separated by intervals of 100 feet. The necessary information for the preparation of such a map was obtained from a study of well records, some of which had been published in the reports of the Indiana Geological Survey. Additional information was obtained from records collected by the writer and from a study of the drillings from deep wells. The map as then constructed disclosed certain outstanding structural features of the surface of the Trenton in Indiana.

Since the publication of that map a large number of deep wells have been drilled in Indiana in portions where deep wells had not been drilled before and by the study of the records of these wells and of many more samples of drillings our knowledge of the position of the upper surface of the Trenton has increased. However, the major features as outlined on the map of 1920 still remain the major features and only minor changes are made in their configurations.

The three most notable features are the geanticline, the northeastern geosyncline, and the southwestern geosyncline. The geanticline is an arch of the surface which extends from the southeastern portion of the state toward the northwestern part. It is commonly called the northwestern arm of the Cincinnati geanticline. The main arch extends northward in the region of Cincinnati. The geanticline in Indiana is marked by three prominent features as outlined by contours drawn on the surface of the Trenton.

The Trenton arch is at its greatest height in the southeastern portion of Indiana where in parts of ten counties it is at 100 or more feet above sea level. This high area extends from Ohio County to the northern portion of Henry County. From the latter point the surface of Trenton descends from an elevation of 100 feet above sea level to an elevation of 200 feet below sea level about the central portion of Miami County. The northern portion of Cass County has an elevation of 300 feet below sea on the surface of the Trenton. Northwest of the latter point the surface of the Trenton rises until in the central part of Lake County it attains an elevation somewhat greater than 200 feet below sea level. The sag in the arch has a width of about 20 miles between the minus-300-foot, or greater, contour lines.

[1] "Petroleum and Natural Gas in Indiana," W. N. Logan, 1920, Ind. Dept. Cons. Pub. No. 8.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

Fig. 1—CONTOUR MAP OF THE UPPER SURFACE OF THE TRENTON LIMESTONE IN INDIANA. Contour interval 100 feet. Contours representing elevations from 100 feet above sea level to 4,500 feet below sea level. Contours outlining the Northwestern Arm of the Cincinnati Geanticline, the sag in the arch, the arch beyond the sag, the northeastern geosyncline, and the southwestern geosyncline.

The arch which rises above the sag in the northwestern portion of Indiana is connected with the elevated area in the northern part of Illinois. From this elevated region the LaSalle anticline extends southward.

The Northeastern Geosyncline. Northeastward from the Cincinnati geanticline in Indiana the surface of the Trenton limestone descends toward the center of the basin in southern Michigan. The pre-Pleistocene rocks deposited on the surface of the Trenton in this area range in age from Ordovician to Pennsylvanian. The southwestern limit of the basin is the geanticline above mentioned. Across the top of the geanticline it is probable that a large part if not all of the formations once extended. It is not probable that these formations were ever as thick as the corresponding ones in the basins.

The dip of the surface of the Trenton away from the axis of the arch is gentle at first, not exceeding ten feet to the mile, but the dip increases as the center of the basin is approached until it reaches 30 or more feet per mile.

The thickness of the formations above the Trenton on the geanticline near its highest point in southeastern Indiana is only 400 feet at

Brookville in Franklin County. At Anderson in Madison County the thickness of the formations above the Trenton is 814 feet. At Kokomo the formations above the Trenton have a thickness of 912 feet.

In the sag of the arch in Cass County at Logansport the surface at the Trenton lies beneath 995 feet of sediments. In the elevated region northwest of the sag at Crown Point in Lake County 723 feet of bed rock sediments overlie the Trenton which lies at an elevation of 183 feet below sea level.

From an elevation of 66 feet above sea level at Anderson in Madison County the surface of the Trenton descends to more than 1,300 feet below sea level at Howe in the northern part of Lagrange County. At the same rate of dip the surface of the Trenton would reach an elevation of approximately 1,500 feet below sea in the northeastern corner of Steuben County. Since no wells have been drilled in that part of the state the record is incomplete for that portion of Indiana.

There is little doubt that minor structural features are present on the surface of the Trenton in the Northeastern Geosyncline. Indications of these are revealed by the 100-foot contour lines but deep-well spacing is not close enough to outline these definitely from present available records, except in a few small areas.

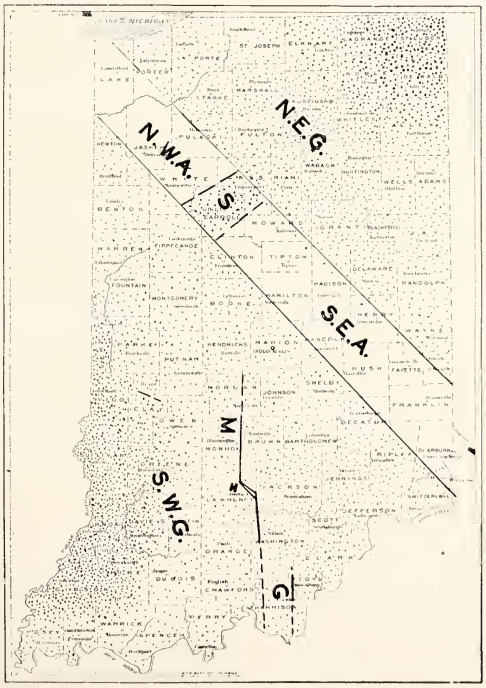

Fig. 2—A STRUCTURAL MAP OF INDIANA. Showing the position of the Northeastern Geosyncline, dotted area, N. E. G., the Southeastern Geanticline, S. E. A., the Sag, S., the Northwestern Geanticline, N. W. A., the Southwestern Geanticline, S. W. G., the Mt. Carmel Fault, M., the Heltonville Fault, H., the Greenville Fault, G.

The Southwestern Geosyncline. Southwest of the Cincinnati Geanticline the largest structural feature is the Southwestern Geosyncline. The surface of the Trenton in this basin descends in a southwestwardly direction from an elevation of 66 feet above sea level on the arch at Anderson in Madison County to 109 feet below sea level at Indianapolis in Marion County. From the latter elevation it descends to 780 feet below at Martinsville, and to 1,332 feet below sea in the southwestern part of Monroe County.

In a southward direction from Crown Point in Lake County the surface of the Trenton descends from an elevation of 183 feet below sea level to 379 feet at Kentland. At Fowler in Benton it has descended to 400 feet below sea, at Rockville in Parke County to 1,412 feet, and at Otter Creek Junction in Vigo County to about 2,000 feet below sea level. Near Robinson in Crawford County, Illinois, the surface of the Trenton lies at an elevation of approximately 3,750 feet below sea level.

By using the same thickness for the formations lying between the top of the Mississippian and the Trenton in the Robinson well for the wells in the lowest portion of the basin in the western part of Gibson County, Indiana, it is assumed that the Trenton lies approximately 4,500 feet below sea in this portion of Indiana, as is indicated by the contour lines on the accompanying map. There is a gradual thickening of formations toward the center of the basin. By taking into account this increase in thickness it is reasonable to assume that since something more than three thousand feet of sediments lie above any evidence of crystalline rocks on the arch that approximately 8,000 feet of sediments lie within the geosyncline in southwestern Indiana. This remarkable thickness of sediments extending in a vertical distance of approximately one mile and one-half forms a notable example of the gradual deepening and filling of synclinal areas.

Minor Features of the Southwestern Geosyncline. One of the most notable features of the Southwestern Geosyncline is the Mt. Carmel Fault which has been traced by the writer from the southern part of Morgan County to the southern part of Washington County. From the latter point the fault apparently passes into a monocline which extends to the Ohio River. In Lawrence County in the region of Heltonville there is a split off from the Mt. Carmel fault which the writer has named the Heltonville Fault. This fault lies at a maximum distance of one mile to the west of the Mt. Carmel.

Rift line. The rift line of the fault is covered in most places by residual materials. There are a large number of places where the limestones of the Harrodsburg, Salem or Mitchell have been brought in contact with the shales or silt stones of the Borden. In such places the Borden is usually covered with residuals but the limestones may stand out as prominent topographic units. On a small branch of Twin Creek north of Mt. Carmel church in Washington County the contact of the Borden with the Harrodsburg and with the overlying Salem is clearly marked. South of this point a line of sinks show the position of the fault line to the Mt. Carmel church. South of the church the Borden lies at the horizon of the Salem. To the east of Clifty Caves about one-

half mile a line of sinks reveal the position of the fault line. Since the Mitchell limestone occupies the surface on both sides of the rift through the southern part of Washington County and the limestone is largely concealed by residual materials indications of its position are not abundant.

Though investigations are not complete for the southern portion of the county indications of the eastward dip of the limestones in some of the quarries are suggestive of the continuance of the fault though for the western part of Harrison County because of steep westward dips monoclinal conditions are suggested.

Tracing of the fault northward from the southern portion of Morgan County is difficult because of the covering of glacial drift over the bedrock formations. West of Mooresville the records of some of the wells suggest fault conditions but not enough information has been secured to warrant extending it to that point.

Nature of Faulting. There is little evidence that faulting has occurred west of the Mt. Carmel fault. If a displacement of the strata is present it is of minor importance. The nature of the faulting seems to have been the downward dropping of a hinged block toward the east. This block varies in width from one and one-half to two miles. From the hinge the strata dip eastward toward the fault line. Since the normal dip of the formations is westward from the hinge-line anticlinal conditions are produced along the hinge. A stretching of the crustal strata by an upward movement east of the fault line or by an upward thrust along the hinge might account for the faulting.

Periods of Movement. Topographic and physiographic evidences of intermittency of movement along the fault line are not found. If they ever existed in the form of hanging valleys on the upthrow side and of broad valleys on the downthrow side these evidences have been removed by the long erosion which has followed the last uplift. There are no striking evidences of rejuvenated streams such as must have been present in the strata along the fault line had not the strata in which these stream valleys were cut been removed by erosion.

In the rocks along the rift line there is evidence of more than one period of movement though there is little evidence that the second movement was of more than minor importance. The time interval between the two movements must have been of considerable duration since the fragments of the brecciated zone were firmly cemented before the second movement took place. Fragments of shale which were included in the limestone fragments during the first period of movement were faulted during a subsequent movement which was sufficiently long after the first for the rock fragments to become firmly cemented. It is evident that these inclusions would not have undergone faulting had they not been firmly held by the cementing materials.

Amount of Throw. The amount of displacement of the faulted block varies at different points along the rift line. Estimates based on levels taken at the contact of the Harrodsburg with the Borden at the fault line and at the hinge line range from 159 feet to more than 200 feet. Estimates made on the rate of eastward dip of the limestone in some localities produce larger results.

Age of the Fault. The youngest beds in contact at the fault line are Mississippian in age. If Pennsylvanian rocks were present they have been removed along the fault line by erosion. It is probable that the faulting occurred during the Appalachian Revolution near the close of the Paleozoic Era. Contemporaneous with that great epeirogenic movement which brought to a close the depositional era in the eastern part of the United States faulting and minor folding took place in the southwestern geosyncline. In the western part of the basin Pennsylvanian rocks are involved in the faulting. These faults appear to be of minor importance in comparison with the Mt. Carmel fault and its associates, the Greenville fault, and the Heltonville fault.

The Heltonville Fault. In the region of Heltonville there is a fault which is apparently a split-off from the Mt. Carmel fault uniting with it at both extremities of the former. The rift line of the Heltonville fault is exposed in the bed of North Leatherwood Creek at a point just east of the wagon crossing under the Southern Indiana railroad. At this point the fault line is approximately parallel with the Mt. Carmel fault which crosses the same creek about one mile to the east. At the fault line in the creek bed the Harrodsburg limestone has been faulted against the Borden shales. The limestone has been much fractured and reunited with calcite, slickensides have been developed, and in places fragments of shale have been thrust into the limestone fragments. Interfingering of limestone and shale also occurs along the fracture zones.

North of Leatherwood Creek the direction of the Mt. Carmel fault is toward the northwest and if the Heltonville fault continues with the same direction northward it must pass into or across the Mt. Carmel fault at a point less than a mile north of the Heltonville fault at the creek crossing. Toward the south the Heltonville fault is traceable to within a short distance of where it apparently again unites with the Mt. Carmel fault. On the Heltonville fault the downthrow is toward the west while on the Mt. Carmel fault it is toward the east. The amount of throw on the Heltonville fault is less than that on the Mt. Carmel.

The Greenville Fault. A fault extends from some point north of Greenville in Floyd County southward toward the Ohio River near Evans Landing. The downthrow of the fault is toward the west. In the southern part of Harrison County the structure may have passed into a monocline with a rather steep dip. Investigations are not complete in this region though some facts have been collected which may throw some light on the problem.

FIBROUS MARCASITE IN CRYSTALLINE CALCITE NEAR LOGANSPORT, INDIANA.

ERNEST RICE SMITH and RUSSELL A. SCHROEDER, DePauw University.

In the quarry of the Logansport Stone and Lime Company about three and one-half miles east of Logansport, near the contact of the Kokomo limestone with the overlying Devonian limestone, there are some very interesting large calcite masses with more or less perfectly developed crystal form. They are embedded in masses of reddish brown clay which appears on casual observation to be residual. The calcite is remarkably well crystalized, in places almost of Iceland Spar clarity, and varies in color from colorless to white, brown and green. On closer examination, the greenish calcite is seen to be colored by a fibrous, greenish gold, metallic mineral, zonally distributed through the outer portions of the calcite masses.

Field observation suggested that the metallic mineral might be Millerite, NiS, but simple laboratory testing showed no trace of nickel. Further careful quantitative analysis by the junior writer showed the mineral to have the composition FeS_2. The results of his determinations are given in the following table:

	I	II	III	IV	V	VI
Weight of crucible	6.4458	6.7037	6.4148	6.4066	6.4461	6.7047
1st weight crucible and Fe_2O_3	6.4742	6.7200	6.4422	6.4398	6.4814	6.7357
2nd weight crucible and Fe_2O_3	6.4736	6.7199	6.4417	6.4394	6.4812	6.7331
3rd weight crucible and Fe_2O_3	6.4734	6.7198	6.4414	6.4392	6.4811	6.7326
4th weight crucible and Fe_2O_3	6.		6.4413			6.7324
Weight of Fe_2O_3	.0276	.0161	.0265	.0324	.0350	.0277
Weight of iron	.0193	.0112	.0185	.0226	.0245	.0194
Fe/55.84	.000345	.000201	.000331	.000405	.000439	.000347

	I	II	III	IV	V	VI
Weight of crucible	6.4470	6.7032	6.4158	6.4066	6.4158	6.5271
1st weight crucible and $BaSO_4$	6.6084	6.7953	6.5715	6.5979	6.6121	6.6895
2nd weight crucible and $BaSO_4$	6.6073	6.7943	6.5711	6.5968	6.6118	6.6881
3rd weight crucible and $BaSO_4$	6.6072	6.7942	6.5709	6.5966	6.6116	6.6880
Weight of $BaSO_4$	.1602	.0910	.1551	.1900	.1958	.1609
Weight of sulphur	.0220	.0125	.0213	.0261	.0269	.0221
S/32.06	.000685	.000391	.000665	.000813	.000869	.000691
Formula	FeS_2	FeS_2	FeS_2	FeS_2	FeS_2	FeS_2

Method of Analysis. I and II, fusion with sodium peroxide with a little glucose added; III and IV, bromine-nitric acid method; V and VI, Escha method of fusion with potassium nitrate.

The color of the sulphide rather indicated that it was Marcasite rather than Pyrite—an opinion which was confirmed by solution in concentrated nitric acid, free sulphur being formed.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

STRATIGRAPHIC UNITS OF THE HARRODSBURG LIMESTONE.

PARIS B. STOCKDALE, Ohio State University.

Field studies of the rocks of the Borden group (Lower Mississippian) of southern Indiana[1] required the writer to make abundant observations of the overlying formation, the Harrodsburg limestone. These were especially necessary in order to establish the position and nature of the contact between the two divisions. In many places, the entire Harrodsburg formation was observed, but in most sections only the lower portion was examined because of its direct application to the stratigraphic problem of the underlying Borden group. Such observance of the Harrodsburg limestone, at closely spaced intervals throughout its unglaciated outcrop belt, served to support the testimony of other Indiana workers that the stratigraphy and fauna of the "formation" need careful attention.[2]

It is not the purpose of this paper to offer a detailed treatment of either the stratigraphy or fauna of the Harrodsburg limestone. The writer's studies have not been sufficiently complete and comprehensive, and his attention in the field has not been directly focused upon such. The broadest conclusion reached is that the Harrodsburg limestone is regionally divisible into legitimate stratigraphic units. Presentation of this phase of the Harrodsburg stratigraphy is the chief aim of this paper.

The Harrodsburg Limestone as a Unit. Recognizing the widespread occurrence, and appreciating uncertainties of correlation, Siebenthal proposed the name "Harrodsburg Limestone" for the calcareous unit which "lies above the Knobstone and between that formation and the Bedford oolitic limestone."[3] The name has been in constant usage since, in Indiana literature. The stratigraphic boundaries of the Harrodsburg limestone have been defined, therefore, as follows: The formation immediately below is the topmost one of the Borden (Knobstone) group; the formation immediately above is the Salem limestone, referred to by Siebenthal as the "Bedford Oolitic Limestone." Siebenthal's type section measured along the highway up "the north bluff of Judah's Creek at the

[1] Most of the studies were made south of the Illinoian glacial boundary, throughout a belt extending from southern Morgan County to the Ohio River at southern Harrison County, an air line distance of 100 miles.

[2] E. R. Cumings called attention to this in Appendix A of his "Nomenclature and Description of the Geologic Formations of Indiana." Indiana Dept. Cons., Div. Geol., Handbook of Indiana Geology, pt. 4, 1922, p. 531.

[3] Hopkins, T. C. and Siebenthal, C. E., The Bedford Oölitic Limestone of Indiana. Indiana Dept. Geol. and Nat. Res., 21st Ann. Rept., 1897, p. 296.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

crossing of the Bedford-Bloomington road, one mile south of Harrodsburg"[4] follows:

Oolitic Limestone.	Feet.	Inches.
Massive fossiliferous limestone	6	0
Gray heavy-bedded limestone	16	0
Blue argillaceous shale	2	0
Limestone	0	4
Chert	0	3
Heavy-bedded blue to gray crystalline limestone	6	0
Yellow calcareous shale with geodes	1	3
Fine, heavy-bedded blue crystalline limestone	11	0
Flaggy limestone	1	0
Gray argillaceous limestone	0	10
Calcareo-argillaceous shale with bands of limestone and some geodes	18	0
Heavy limestone, weathering shaly	3	0
Calcareous shale in bed of creek	?	?
	67[5]	8

Siebenthal described the formation as follows: "The Harrodsburg limestone varies from 60 to 90 feet in thickness. It forms a belt four or five miles in width lying along the eastern outcrop of the oölitic, rising gradually toward the east at the rate of 50 or 60 feet to the mile, and bordered by the broken hills of the Knobstone region.

"The 'beds of passage' from the Knobstone to the Harrodsburg limestone contain great numbers of geodes, or, as they are more familiarly termed, 'mutton heads,' ranging from the size of a pea up to 18 or 24 inches in diameter. These geodes are confined to the lower members of the Harrodsburg limestone, though a few are scattered through the Knobstone.

"Above the geode layers there is a bright gray or blue highly crystalline and quite fossiliferous limestone with small crystals of pyrite, giving it in places a greenish tint. Many of the bedding planes are marked by 'crowfeet' (stylolites), and intercalated lenticular masses of chert are very plentiful. The residual clay is very stiff and of a deep-red color.

"Towards the top of the limestone the strata become more massive, and at the top of the upper four to eight feet usually have lost the molluscan character of their fauna and consist almost wholly of comminuted bryozoa. . . ."[6] It should be noted that the "beds of passage" were included in the Harrodsburg unit.

Some uncertainty as to the exact contact of the formation with the overlying and underlying rocks was recognized by Beede, who wrote: "The Harrodsburg limestone is from 70 to 90 feet in thickness in the quadrangle. The lower part is interstratified with shales and some soft sandstones. The lowest limestone was taken as the base of the Harrods-

[4] Hopkins, T. C. and Siebenthal, C. E., *Ibid.*, p. 297.

[5] This should be 65 feet 8 inches. Siebenthal added incorrectly.

[6] Hopkins, T. C. and Siebenthal, C. E., *Ibid.*, pp. 297-298.

burg. However, since there is a tendency for these lower layers to be lenticular it is not certain that the mapping is absolutely uniform in this respect. In fact it is pretty certain that this is not the case. However, the variation is but a few feet, probably not varying beyond the limits of accuracy of mapping on the present base map.

"In a general way the Harrodsburg is a very coarse crinoidal limestone in its lower part, a calcirudyte, becoming finer near the central part where the crinoids and large brachiopods and pelecypods are replaced with bryozoa. Near the top it assumes very much the character of the Salem limestone or 'Bedford oolite' above, a calcarenyte. However, so far as the rocks of this quadrangle are concerned, careful inspection with the lens will differentiate them at once. At the overhead bridge across the Monon track, between Smithville and Sanders, the two are nicely separated by a strong stylolite seam. Much of the way they are separated by a brownish bituminous marl, which locally replaces the base of the oolitic limestone. At other places it is difficult to say within two to five or six feet just where the contact is. The upper part of the Harrodsburg is composed of comminuted bryozoan remains with certain elongate particles whose nature has not yet been made out. . . ."[7]

Full treatment of the Borden-Harrodsburg contact cannot be presented in this brief paper. In general, it may be said that the contact is determinable in the outcrop belt north of T. 3 S., R. 5 E., southwestern Floyd County. To the south, in Harrison County and in adjacent parts of Kentucky, the contact is clouded because of the rather quick change of facies of the uppermost Borden member to a calcareous, cherty phase which is itself very similar in appearance to the normal, basal Harrodsburg. Lack of appreciation of this facies change in the upper Borden has misled a number of observers from the proper interpretation of the Harrodsburg-Borden relationships.

Only a careful study of the Harrodsburg-Salem association will fix satisfactorily the position of the top of the Harrodsburg limestone. This is especially true because of uncertainty regarding the gray to buff, calcareous, shaly zone which appears in many places between the "typical Salem" above, and the definite Harrodsburg limestone below. This shaly zone is particularly common in southern Floyd County and in southeastern Harrison County, as well as in exposures across the Ohio River in Kentucky. In one of the quarries at Edwardsville, this zone is five to seven feet thick; at Locust Point, along the road up the steep bluff, near center sec. 13, T. 4 S., R. 5 E., it is 20 feet thick; along the road one and one-fourth miles north of Stewart Landing, southeast of the center sec. 26, T. 4 S., R. 5 E., it is 13 feet thick; near the top of the large quarry at West Point, Kentucky, a similar zone 12 feet thick can be recognized. Malott has called attention to a much greater thickness of this shale in the vicinity of the village of Buena Vista, southeastern Harrison County. In eastern Monroe County at a quarry in the hillside, immediately east of the road, west-center sec. 27, T. 8 N., R. 1 E., where there is an unusual exposure of both Harrodsburg limestone and Salem

[7] Beede, J. W., Geology of the Bloomington Quadrangle. Indiana Dept. Geol. and Nat. Res., 39th Ann. Rept., 1915, p. 195.

limestone, this buff shaly zone is found about five feet in thickness. The appearance of the Salem limestone there, which is a considerable distance east of the main outcrop belt, is on the downthrow (west) side of the fault, where the amount of throw is exceptional. The total Harrodsburg thickness there is 62 feet. The shaly zone described above is, however, in many places quite thin or non-existent.

The question of the correlation of the Harrodsburg limestone with other Mississippi Valley formations has been considered by numerous workers. Controversy over the Keokuk or Warsaw age of the formation ended finally in favor of the Warsaw. Excellent and complete treatment of the Harrodsburg correlation is given by Cumings.[8]

DIVISIONS OF THE HARRODSBURG LIMESTONE.

A sub-division of the Harrodsburg limestone into units is justified by a scrutiny of many sections carefully measured, and of others casually observed. Figure 1 shows a generalized section for southern Indiana. In the first place, it is evident that the formation is divisible into two main parts, to which the writer, at this time, is not offering names, but is merely using the designations "Upper" and "Lower." In the second place, it is to be noted that these major divisions are separable into smaller units, or members. The Upper Harrodsburg has not been carefully studied by the writer, and, consequently, no attempt is made to give it a final subdividing nor a naming of probable members. The Lower Harrodsburg, which has been critically observed, reveals three recognizable and persistent units. The proposed names for these members, in ascending order, are "Ramp Creek," "Leesville," and "Guthrie Creek."

Lower Harrodsburg. The two-fold nature of the Harrodsburg is at once apparent to those who have made regional observations: (1) a lower part, which is in the main very impure and variable, characterized by numerous geodes, much chert, and irregularly spaced crinoidal layers, one of which is persistent; (2) an upper part of fairly pure limestone in the main, in places highly crystalline and often quite fossiliferous.

The Lower Harrodsburg includes all the irregular and variable, impure unit lying between the uppermost Borden member below and the overlying, fairly massive, more regular limestone. Except for crinoidal lenses, this division is a highly siliceous, fine-grained stone, known to the quarryman as "bastard rock." In places it may be well-called a calcareous sandstone. When fresh it is light-gray to blue-gray. A high iron content gives it a characteristic buff to yellow color when weathered. This siliceous phase is quite brittle, and upon weathering splits up into irregular, flattened chips, broken off in a direction diagonal to the bedding. These same features are, in part, characteristic of the calcareous facies of the upper Borden in southeastern Harrison County, and in the adjacent parts of Kentucky.

Interbedded within the Lower Harrodsburg, and forming a large part of it in places, are hard, resistant, crinoidal lenses, ranging from a few

[8] Cumings, E. R., *Ibid.*, pp. 493-496.

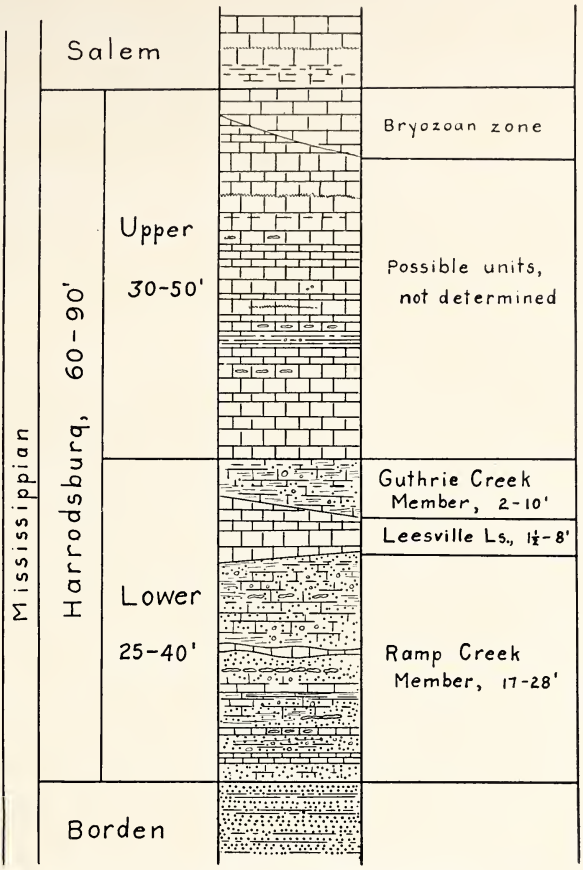

Fig. 1—Generalized section showing divisions of the Harrodsburg limestone in southern Indiana.

inches to as much as eight feet in thickness. One crinoid layer is persistent and gives a basis for subdividing the unit into its three members. Crinoid streaks and irregular patches are common. In places the rock is shaly. Stylolite-seams are not common because of the siliceous nature of most of the rock. Chert, varying in amount, is usually abundant, occurring as nodules and lenses, and is white to buff in color. Some of the chert is silicified crinoidal limestone. Geodes characterize the Lower Harrodsburg and are also in the underlying Borden strata, where they are usually much smaller and less numerous.

The following sections illustrate the general nature of the Lower Harrodsburg: (a) Section one and one-fourth miles east of Harrodsburg, Monroe County, measured along a ravine running east from the road forks, a short distance east of the center of sec. 28, T. 7 N., R. 1 W.:

Upper Harrodsburg limestone.

Lower Harrodsburg:	Feet
Partially covered, buff shaly zone (Guthrie Creek member)	3½
Crinoidal limestone, in layers of varying thickness (Leesville limestone)	4½
Shaly, siliceous limestone, weathering yellow	3½
Crinoidal limestone	½
Siliceous limestone, gray to buff	1½
Slabby, coarse, crinoidal limestone, with siliceous streaks	3½
Siliceous limestone, gray to yellow, with crinoid streaks	3½
Irregular crinoidal limestone, with chert and geodes	2½
Siliceous limestone, gray to yellow	6½
Siliceous, crinoidal zone	1½

Borden, blue-gray, sandy shale.

The lower 23 feet of the above section constitute the Ramp Creek member. Chert and geodes are common to the brittle siliceous zones.

(b) Leesville section, measured in quarries and along U. S. highway No. 50, immediately west of the bridge across Guthrie Creek, one-fourth mile southeast of Leesville, Lawrence County, near center NE. ¼ sec. 27, T. 5 N., R. 2 E.:

Upper Harrodsburg, mainly coarse, crinoidal limestone.

Lower Harrodsburg:	Feet
Blue-gray, calcareous, sandy shale, weathering buff to yellow (Guthrie Creek member)	7
Coarse, blue-gray, crystalline and crinoidal limestone (Leesville limestone)	6
Blue-gray, variable, siliceous, brittle limestone, with irregular streaks and small patches of crinoids; weathers to yellow color; small geodes; much chert	20
Crinoidal limestone	0 to 2
Brittle, sandy limestone	1½

Borden, massive sandstone.

(c) Edwardsville section, measured along State highway No. 62 and adjacent quarry, immediately northeast of Edwardsville, Floyd County, NE. ¼ NE. ¼ sec. 1, T. 3 S., R. 5. E.:

Salem Limestone, massive, typical.	Feet
Argillaceous limestone, weathering buff, with shaly appearance	7
Upper Harrodsburg limestone	32
Lower Harrodsburg:	
Gray to yellow, shaly, siliceous limestone (Guthrie Creek member)	5
Gray, compact, coarsely crinoidal limestone (Leesville limestone)	2
Siliceous, gray to blue limestone, with thin, irregular crinoidal lenses	7
Irregular crinoidal limestone, with siliceous patches	4

Gray, weathering yellow, very irregular limestone; mostly siliceous, with small geodes and much chert..... 10
Brown, crinoidal limestone..... 2½
Dark-gray, brittle, calcareous sandstone, with crinoid streaks 4½
Borden standstone.

The lower 28 feet of the Lower Harrodsburg of the above section constitute the Ramp Creek member (see fig. 2).

The most persistent feature of the Lower Harrodsburg, which impresses one who has made many observations throughout the entire outcrop belt, is a hard limestone layer which often displays itself as an overhanging bench in sharp ravines, producing a waterfall. The possibility of this "waterfall-former" being a continuous layer and a definite

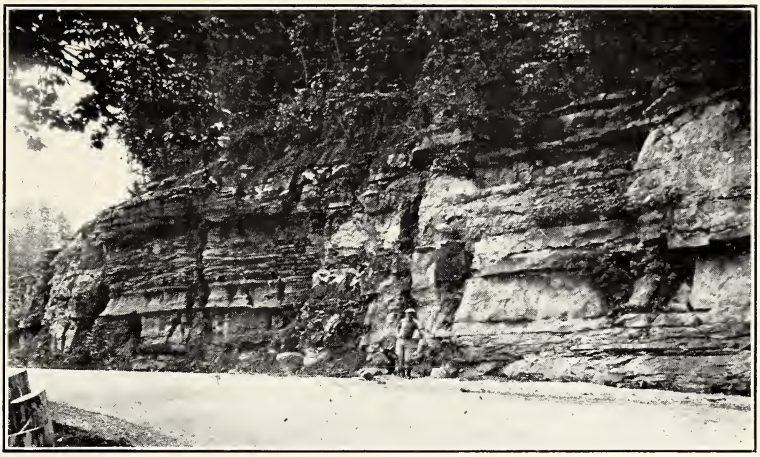

Fig. 2—The Ramp Creek member as seen in the Edwardsville section, exposed along State Highway No. 62, immediately northeast of the village of Edwardsville. NE. ¼ NE. ¼ Sec. 1, T. 3 S., R. 5 E. The contact with the Borden is indicated by the man's hand.

stratigraphic unit was recognized by Malott. Extensive study has revealed a persistent shaly to siliceous zone, weathering buff to yellow, immediately above this limestone layer, and between it and the overlying "typical" Harrodsburg limestone of the upper division. Below this waterfall-forming layer is the variable "bastard" rock, previously described. Other crinoidal lenses locally cause waterfalls, and may easily be confused at first with the main limestone member.

The name *Leesville Limestone member* is here proposed for the unit described above. The name is taken from the village of Leesville at the eastern edge of Lawrence County. The Leesville section (b) shows this member in its typical occurrence. Here it is a heavy, coarse-grained, blue-gray, crystalline and crinoidal limestone, six feet thick. At the time of this writing, it is exposed on both sides of the road, and near the top of the abandoned quarry immediately south of the road. It is

responsible for numerous waterfalls in nearby ravines. In this type section it is plainly delimited both above and below. Above it is the seven foot zone of calcareous shale to shaly limestone, which weathers light yellow. Above this is massive limestone of the Upper Harrodsburg. Directly below the Leesville limestone at this section, is variable, calcareous rock, quite siliceous, about 22 feet thick. The Leesville limestone ranges from one and one-half to as much as eight feet in thickness. Between four and five feet is an average thickness. Throughout the entire outcrop belt, its stratigraphic boundaries are persistently similar to those of the type section. That it is not as discernible in some places is due to improper exposure of the overlying unit and greater abundance of confusing crinoidal lenses below. The member is especially pronounced and valuable in southern Floyd and southeastern Harrison counties. Here it serves as an excellent key horizon for stratigraphic and structural studies, especially since the base of the Harrodsburg is indefinite.

Guthrie Creek member is the name proposed for the shaly to siliceous limestone unit lying immediately above the Leesville limestone. It is overlain by the Upper Harrodsburg limestone. The name is taken from Guthrie Creek, along which, in southeastern Lawrence County, the member is often exposed. In its typical occurrence, it is seen in the heretofore listed Leesville section (b) located adjacent to Guthrie Creek. Here as previously stated, it is seven feet thick; it is quite shaly, and has a number of large geodes. In other exposures it is often less shaly and is more sandy. Buff to light yellow is the characteristic color of the weathered rock in all exposures. Where unweathered, the rock is blue-gray and does not display, so well, its shaly nature. In most places this member is more shaly and weathers less yellow than the rock beneath the Leesville limestone. It ranges in thickness from two to 10 feet, with an average of about five feet.

For the main part of the variable, siliceous limestone with crinoid lenses, which lies between the Borden sandstone or shale below and the Leesville limestone above, the name *Ramp Creek member* is proposed. This is taken from Ramp Creek of southeastern Monroe County. In numerous tributary ravines, this member, and the underlying and overlying rocks are excellently exposed. A good type section is revealed in a headwater ravine which crosses the secondary road, and which runs southeast from near the eastern margin of NW. ¼ NW. ¼ sec. 35, T. 8 N., R. 1 W., one mile northeast of the village of Sanders. Here the following strata are exposed, the upper part along the road, and the main portion in the ravine:

	Feet
Upper Harrodsburg limestone	3
Lower Harrodsburg:	
Buff, siliceous, somewhat shaly limestone, with crinoidal patches (Guthrie Creek member)	2½
Massive, light gray, crinoidal limestone (Leesville limestone)	3½
Variable, impure limestone, mostly gray to yellow, siliceous and brittle; irregular crinoidal lenses up to eight inches thick; streaks of chert; geodes	15

Slabby, coarse, crinoidal limestone..... 3
Somewhat variable, more massive crinoidal limestone, with stylolites 3
Borden, sandy shale.

The lower 21 feet compose the Ramp Creek member. This exposure, and the exposures of the three sections (a, b, c) previously listed, show the general nature of the Ramp Creek member (see fig. 2). They demonstrate the distinctive variability. The predominance of brittle, siliceous limestone which weathers yellow; the presence of irregularly distributed crinoidal lenses, varying in thickness and often disappearing

Fig. 3—A sharp Harrodsburg-Borden contact made by a basal crinoidal limestone lens. The Borden rock is here a very shaly sandstone. This exposure is in the bank of a small stream, near the southwest corner sec. 22, T. 8 N., R. 1 W., about one and one-half miles southeast of the village of Clear Creek.

laterally, passing into the siliceous phases; and the prevalence of geodes and chert, are all characteristic of this member. The sharply defined crinoidal lenses furnish incentive for a unique, separate study. In some localities, as immediately north of Bloomington, these lenses are abundant; in others, as at Leesville, they are rare. In many places a crinoid layer marks the contact with the underlying Borden (see fig. 3); in others, such a layer is absent. The thickness range of the Ramp Creek member is 16 to 28 feet; the average thickness, about 22 feet.

The Lower Harrodsburg averages about 32 feet in thickness; the minimum is 25 feet; the maximum, 40 feet. The following table shows the approximate thicknesses of the Lower Harrodsburg members at or near a number of places:

Locality	Guthrie Creek member	Leesville limestone	Ramp Creek member	Total thickness
Mt. Tabor.....	2	2	24	28
Bloomington.....	6	5	16	27
Smithville.....	3	3	20	26
Patton Cave.....	2	3	25	30
Harrodsburg.....	3	5	23	31
Leesville.....	7	6	22	35
Borden.....	7	5	21	33
Georgetown.....	5	3	27	35
Edwardsville...	5	2	28	35
Rosewood.....	5	6	30?	41?
Evans Landing...	4	8	31?	43?
West Point, Ky..	5	10	25?	40?

Upper Harrodsburg. In striking contrast with the Lower Harrodsburg, the upper division is a more regular, more massive, and much more pure limestone. It is usually light gray to blue-gray in color, in some places tinted green. It lacks the yellow color upon weathering. Much of it is crystalline, and much is quite fossiliferous. Stylolites are common. Chert is far less abundant than in the Lower Harrodsburg. Shaly partings are not infrequent.

Of unusual interest is a zone at the top consisting almost entirely of comminuted bryozoa, commonly from four to 10 feet in thickness. This may be of a bioherm nature. The thickness of Upper Harrodsburg ranges from 30 to 50 feet, the common thickness being about 35 feet.

As previously stated, this paper is not offering a detailed treatment of the Upper Harrodsburg, and does not suggest the subdivisions of it. More intensive study is necessary to reveal its probable stratigraphic units. However, the fact has been clearly revealed that the Upper Harrodsburg is a distinct division, worthy of separate consideration from the Lower Harrodsburg.[9]

[9] The writer is especially indebted to Professors E. R. Cumings and C. A. Malott, of the Department of Geology, Indiana University, for valuable suggestions and assistance.

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A STRIKING CASE OF DIFFERENTIAL EROSION.

FRED J. BREEZE, Ball Teachers College.

Near the mouth of Bear Creek, a small tributary of the West Whitewater, stands a terrace about 50 feet above the bed of this creek. By the undercutting of Bear Creek this terrace presents an almost vertical cliff. The upper 40 feet of this cliff consists of sand, gravel, and numerous slabs of limestone. The lower 10 feet consists of fine textured material, which at some distance away appears to be clay; at a short distance this shows thin layers lying in an almost horizontal position. In a few places where water has trickled down the face of the cliff, an unusual case of differential erosion was seen. In these places the face of the vertical cliff presented a well defined corrugated surface, with the corrugation running horizontal. The corrugated surface consisted of alternate ridges and grooves with an average width of about one-half inch. Each groove was an undercut area beneath the overhanging, very minute projecting ledge of more resistant material. As this band of material was wet there seemed to be no difference in the layers into which the grooves were cut and the layers of more resistant material which stood out as ridges; but samples brought into the laboratory when partly dried showed a striking color difference in the alternate layers. The layers into which the grooves were cut were distinctly light in color. Those standing out as ridges were decidedly dark. Even where the layers were extremely thin, in some cases 20 layers to the inch, the light colored limestone layers stood out in striking contrast to the dark greasy layers of clay. The hydrochloric acid test revealed that the light colored layers consist of limestone silt. The dark layers consist of clay of a texture fine enough to give a distinctly greasy feel to the fingers. In cutting a sample of the material, it seemed to have the consistency of a bar of soap and when a smooth cut surface was held in drip of a faucet a corrugated surface was developed in a minute or two. A rubbing of the dry surface with the fingers in a few seconds produced a distinctly corrugated surface. The calcareous silt exists in such a loose state that a thin stream of water down the face of the cliff produces the very distinct corrugated face.

The upper ten inches of this thin-bedded material was brownish in color, and gave the appearance of a partly consolidated sandstone. Examination revealed that it consisted mostly of iron-stained particles of clay and limestone, with a small amount of very fine silica sand. Some of the layers of this iron-stained material were very thin. The changes from this to the coarse, stony and gravelly material above is abrupt.

A study of this stratified material presents an interesting problem of sedimentation. The source of the limestone silt and the clay is near

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

at hand. The country rock of this locality consists of alternating thin beds of shale and limestone. Glacial ice reduced these strata to a fine powder; and in areas of still water beyond the edge of the melting ice this pulverized material was deposited. Do these alternating layers of clay and limestone silt represent an alternation of quiet and less quiet water in the area of deposition, due to seasonal or daily variation in the melting of the ice? In other words, what were the varying conditions that caused this type of sedimentation? Are these layers varves? Laboratory trials have failed to obtain this alternation of material in sedimentation. A study of this type of sedimentation is still in progress.

GEOLOGICAL INFORMATION FROM THE MONROE AND LAWRENCE COUNTY SOIL MAPS.

T. M. BUSHNELL, Purdue University.

Soil survey maps and reports of Monroe and Lawrence counties, Indiana were published in 1928. The Bloomington quadrangle topographic sheet was used in part of Monroe County, but the rest of this county and all of Lawrence County were made by plane table traverse. The land was covered closely enough to see practically every 10 acres of land in the counties. The maps show all public roads, many private roads, houses, streams, churches, schoolhouses, towns, railroads, etc.

The soil survey reports tell of many correlations between the soil types and geology, topography and physiography.

From the soil types the reader may trace the outlines of uplands, terraces and first bottoms. Certain types are always on smooth level land, others on steep hillsides and still others in intermediate positions so it is easy to read certain topographic information from the soil map.

In the more rolling land there is frequently a very close correlation between the underlying geological formations and the soil types. This is so consistent that in many places, on the Bloomington quadrangle geological map, the soil boundaries could be traced directly from the geological boundary. In smoother topography the effects of weathering have so overbalanced the effects of parent materials that certain soil types cross several formations without changing appreciably.

By means of the correlations mentioned above it is possible to trace out quite accurately in these two counties the location and area of the Chester, Mitchell, Salem and Harrodsburg, and Knobstone formations. The Heltonville fault may be traced across the two counties.

The glacial boundary and old glacial lake Flatwoods are revealed on the map. There are a number of old glacial terraces or lacustrine deposits in the Salt Creek and Bean Blossom valleys.

The McGary silt loam shows the location of a peculiar backwater deposit very high in lime, which has a wide distribution along the Ohio River and its tributaries.

The soil map also reveals the location of numerous peculiarities in the drainage systems and such minor matters of interest as the geode beds along the contact of Harrodsburg and Knobstone formations; a Tertiary gravel ridge near Buddha, etc.

In lieu of geological maps and surveys in Monroe and Lawrence counties, geologists may find that the soil maps and reports record considerable geological information which may aid in solving some of their problems.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

SPECIAL TOPOGRAPHIC FEATURES AND THE PHYSIOGRAPHIC BACKGROUND OF THE BLOOMINGTON INDIANA QUADRANGLE.

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The purpose of this paper is to present a brief description of the chief topographic characteristics of the Bloomington Indiana Quadrangle. It is rather unusual that an area of country which is bounded by arbitrary methods should possess so many features of interest to the physiographer and geologist. It is true that much of its topography is but a continuation of that beyond the mapped limits; nevertheless, the positional relations of the area are such that one finds great diversity of topographic forms and a grouping of physical features that would be difficult, if not impossible, to find in other locations.

It was the privilege of the writer as a student of Indiana University, to make a study of this region. As a part of the study and as an aid to the interpretation of its topographic features, a relief model of the area was constructed. The model has the advantage of showing at a glance the positional relationships of the varied surface features to one another and to the structural conditions of the rock formations—relations that are not so easily interpreted from the flat map and which are more or less difficult to determine in the field.

Positional Relations.

Location and Area. The Bloomington Indiana Quadrangle was topographically mapped by the United States Geological Survey during the years of 1907 and 1908. According to this survey, the boundaries were established as the meridians of 86° 30′ and 86° 45′ W. and the parallels of 39° and 39° 15′ N. The quadrangle is 15 minutes square and contains approximately 231 square miles. In includes portions of Owen, Monroe, and Greene counties. Monroe County forms the largest part of the area. The quadrangle is named for the city of Bloomington, which is located in the northeast part of the area.

Major Physiographic Divisions. The quadrangle is a small part of the Central Plains area of the United States. According to Fenneman's classification of physiographic divisions it would fall in the Interior Plains Division, Interior Low Plateaus Province, and in the Western Section (unnamed) of that province. Although this positional relation is not a special one, it is mentioned here because of the fact, that in the treating of a local area, it is easy to overlook the larger physiographic divisions of which it is a part. As a part of a larger physiographic division the area has been subjected to much the same influences of denuda-

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

tion and climate that have given to the larger unit its outstanding surface characteristics. Detailed differences in its surface characters are to be interpreted from the study of local environments.

The Bloomington Quadrangle is a region that well merits consideration from the standpoint of the positional relations that have influenced the development of its topography; and perhaps, it is not excelled elsewhere in the number of local physiographic studies that it affords.

Minor Physiographic Divisions. Relative to the Interior Plains division, the physiographic divisions of Indiana are smaller units of the larger division. In "The Physiography of Indiana," Malott recognizes for the south portion of the state from east to west the following units: Dearborn Upland, Muscatatuck Regional Slope, Scottsburg Lowland, Norman Upland, Mitchell Plain, Crawford Upland, and Wabash Lowland. Three of these physiographic divisions are represented in the Bloomington quadrangle viz., the Norman Upland, Mitchell Plain and Crawford Upland. Of these the Mitchell Plain and Crawford Upland are more typically represented in the area than the Norman Upland. The following figure illustrates the positional relation of the quadrangle to these physiographic units. (Fig. 1.)

Fig. 1—The location of the Bloomington Quadrangle is shown by the square. The figure shows its relation to the physiographic divisions of the state.

Illinoian Glacial Margin. The larger part of the quadrangle is in the unglaciated section of the state. (Fig. 2). The Illinoian Glacial margin however, crosses the extreme northwestern part of the area. Near Stogsdill pond, sections 2 and 3, T9N, R3W, there is the remnant of an old glacial moraine in which quartzitic and granitic boulders may be found. The moraine is not extensive and within a short distance abuts against a bed rock ridge. A possible explanation for Stogsdill pond is that it occupies a morainic depression. The pond is of further interest in that it contains a relic Arctic flora, particularly a species of water lily that covers a large part of the pond's surface.

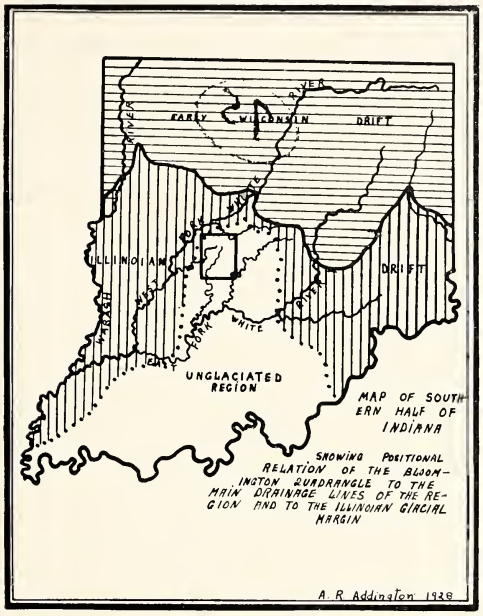
EARLY WISCONSIN DRIFT
ILLINOIAN DRIFT
WHITE
UNGLACIATED REGION
MAP OF SOUTHERN HALF OF INDIANA
SHOWING POSITIONAL RELATION OF THE BLOOMINGTON QUADRANGLE TO THE MAIN DRAINAGE LINES OF THE REGION AND TO THE ILLINOIAN GLACIAL MARGIN
A. R. Addington 1928

Fig. 2—The quadrangle is represented by the square. The stream shown crossing the northeast corner of the quadrangle is Beanblossom Creek. The stream crossing the southeast corner is Salt Creek. The stream heading near the central part of the area is Indian Creek. The stream flowing from the western part of the area is Richland Creek.

The greater part of the glacial materials in this part of the quadrangle are relatively fine, consisting of silts, sands, and gravels that are more typical of glacial outwash than glacial moraine. These deposits form for the most part but a veneer over the solid rock, so that the latter exercises the dominant surface control.

Drainage. The drainage of the quadrangle is a part of the Mississippi drainage. The immediate large streams adjacent to the area are the West Fork of White River situated to the west and north and the East Fork of White River situated to the south. The topographic divide for these streams passes through Bloomington and may be traced in a general southwesterly direction across the quadrangle. (See fig. 2).

Considering the area as a whole, the drainage is characteristically surface drainage, but where limestone forms the subsurface rock subterranean drainage is excellently developed. This type of drainage is best developed near the entrenched valleys and valley heads that margin the limestone platform.

It is somewhat interesting to note that the apparent topographic divide between the forks of White River does not exactly coincide with the division of drainage to these streams, since some of the drainage is diverted through subterranean routes beneath the topographic divide. A specific example of this sort of thing is illustrated near Truitt's Cave, where a small stream sinks into the limestone, passes beneath the sandstone capped ridge, and emerges as a spring in a small tributary to Richland Creek. Richland Creek is tribuary to the West Fork of White River, entering the latter near Bloomfield, Indiana. The drainage that now passes through the subterranean route above mentioned formerly was a part of Indian Creek drainage, which is a tributary to the East Fork of White River. The above is not the complete story of the drainage changes occurring in this region, but it serves to illustrate a shifting of drainage divides by an interesting case of stream diversion.

Geological Formations. It is rather difficult to give special attention to the topographic features of the quadrangle without taking into

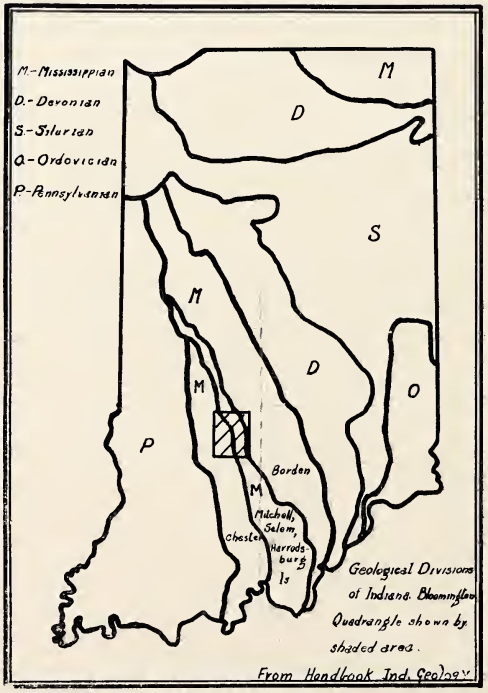

Fig. 3—The figure shows the relation of the quadrangle to the regional distribution of the geological formations. The outcrops of Pennsylvanian rocks on the quadrangle are not indicated by the figure.

account the areal extent, stratigraphical relations, and lithologic characteristics of the rock formations, for the latter form, so to speak, the foundations upon which the topographic architecture stands. The positional relations of the quadrangle to the geological formations can best be understood by reference to figure 3. It will be noted that the strike and dip of the formations and their general stratigraphical relations are representative of the south part of the state as a whole.

The rock formations having outcrop in the quadrangle are Paleozoic sediments of Mississippian Age with a little of the lower Pennsylvanian capping the ridge crest in the western part of the quadrangle. There are upon some of the higher elevations, notably in the southern part, gravels of Tertiary Age, and in the northern and northwestern portions the glacial materials, previously mentioned, which belong to the Pleistocene. So far as influence upon topographic development is concerned, the Paleozoic sediments and the Pleistocene deposits are the most important for this region.

If one crosses the state from east to west he passes over successively younger formations. In order these formations belong to the Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian systems. On the quadrangle the Mississippian and Pennsylvanian systems are represented by the following formations in order from east to west and oldest to youngest: the Borden Series (Riverside sandy shale member), the Harrodsburg limestone, the Salem limestone, the Mitchell limestone, the Chester series, and the Mansfield sandstone. The Chester series consist of intercalated sandstones, limestones, and shales that constitute the most complex geology of the entire area.[1]

PHYSIOGRAPHIC PROCESSES INVOLVED.

Diastrophism. Ancient crustal movements that gave rise to the Cincinnati Anticline were responsible for the gentle westward tilting of the rock formations in this region. The central axis of the anticline extends in a general NW.-SE. direction across the state, so that areas located in the central southern section are underlaid by westward dipping sediments. A glance at figure 3 will make this general relation clear. This diastrophic movement is responsible for the present attitude of the subsurface strata and they in turn exert an important control upon the topographic development of the region. The topography would be noticeably more uniform if the rocky formations were horizontal.

It should here be pointed out that more recent crustal movements, especially during the Tertiary, and perhaps following the Pleistocene have contributed to the present topographic condition. The present altitudes of the Early and Late Tertiary peneplain remnants, the deep dissection of the uplifted peneplains, and certain drainage adjustments, are a few of the results, directly or indirectly, of these more recent crustal movements.

[1] For the details of the Geology of the Bloomington Quadrangle, see J. W. Beede and others, *Geology of the Bloomington Quadrangle*, 39th Ann. Rept. of the Ind. Geol. Survey, for 1914 (1915), pp. 190-229. Also Handbook of Indiana Geology, 1922, pp. 475-530.

The Processes of Denudation. The processes of weathering and erosion are the important processes that operate upon any elevated land mass. Given sufficient time the total result of their work is regional denudation and the resultant land form is the peneplain. The peneplain stage is not attained, however, without the appearance, modification, and eventual disappearance of many diverse topographic forms, and it is they that environ us as silent reminders of the regional transformation now in progress.

The processes of denudation operate chiefly through the agencies of wind, water in its various forms, atmospheric gases, and organisms. It is a very difficult thing to assign to an agent or process its relative importance in creating the topography of a region, especially, a region where numerous agents and processes are involved. The Bloomington Quadrangle is an area representative of this condition. Here the agencies of running water, groundwater, glacial ice, and the mechanical and chemical processes of weathering are evidenced by the existing topographic forms. Perhaps the outstanding topographic expression of the region is its intricate network of ridges and valleys, which, especially in the western part of the area, are conspicuously molded. With certain local exceptions, the remainder of the region has extensive ridge and valley development, but with a softness of detail that stands in marked contrast to the bold and rugged features of the western part. This ridge and valley topography is most certainly to be associated with the agency of running water, but there are other factors and processes to be considered if interpretation of local topographic differences is attempted.

CONDITIONING FACTORS INVOLVED.

The topography of a region is not solely due to the processes that have operated upon it. The topography is conditioned to some extent by the climate of the region, by the attitude, exposure, and lithologic characters of the subsurface rocks, by the altitude of the region, and by the length of time the processes of denudation have been at work.

Climate. Climate as a factor in topographic development should be considered as the sum total of weather conditions rather than the average weather. It is not the average weather that operates upon a region to make that region what it is, but the conditions imposed by the weather cause the operation of certain processes which produce the results. In this respect climate is a very fundamental control, for its elements of temperature, moisture, and wind are the very bases of origin of the physiographic agents and physiographic processes that modify the land's surface.

The Bloomington Quadrangle is in a climatic region where the elements of temperature and moisture assume the ascendency as climatic controls. It is impossible to assign definite values to the relative importance of these elements as factors in the topographic development of this region.

Rock Attitude. The fact that the rocks of this region are tilted brings to the surface a series of rock formations of different lithologic characters. The amount of tilting and the thickness of the formations governs the amount of their areal exposure. Obviously, other conditions remaining constant, the topography of this region would be considerably different from what it is now, were the rock formations tilted at any greater angle or were they horizontal.

Under the present conditions of tilting there is exposed within relatively short distances several different types of rock each of which supports its own type of topography.

The cuesta-like form, to be observed in the southern part of the quadrangle, is a feature that owes its existence just as much to the tilting of the subsurface rocks as it does to the processes that have operated upon them.

Lithologic Characters. The influence of lithologic control is most strikingly brought out where there are marked changes in lithologic units. In the Bloomington Quadrangle the verity of this statement is attested by the development of a karst topography with its numerous sinks, swallow holes, caverns, and disappearing streams, which are most characteristically found in those areas where the Mitchell limestone is the immediate subsurface rock. Where the Riverside member of the Borden series forms the subsurface, karst features are absent and steeply walled valleys, well graded valley floors, and absence of sheer cliff exposures are characteristic. The first is a well jointed, thin bedded, dense limestone, and the second is a relatively little jointed, impervious, shaly formation. Surely, this is sufficient evidence that topographic variations are in part due to differences in rock characters.

Altitude. The altitude of a region is a factor in its development for altitude determines the depth to which a region may be entrenched by streams. In general, the higher the region above the sea, the bolder its topography.

The Bloomington Quadrangle is a region of moderate elevation; consequently, pronounced or extreme entrenchment by streams is impossible under the present altitude conditions. But in so far as relative ruggedness or boldness of topographic forms is directly related to the amount of stream entrenchment, which in turn is dependent upon the altitude of the region, it is necessary to consider altitude as a factor in topographic development.

Time Factor. To those who are familiar with geological processes it is unnecessary to comment upon the importance of time as a factor attendant upon changes of the land's surface. Let it be sufficient to say that the evolution of the present topographic forms represent the processes of land sculpture that have operated through long time periods. The topographic forms are what they are, in part at least, because of the time during which the sculpturing processes have been at work.

TOPOGRAPHIC FEATURES ADJACENT TO THE ILLINOIAN GLACIAL MARGIN.

There are a number of topographic features represented that are associated with the Illinoian glacial margin. For the most part, these features are the result of drainage adjustments attendant upon the advance and recession of the Illinoian ice sheet. A very small amount of the topography is due directly to glacial deposition.

Lake Flatwoods Basin. Near the north margin of the area and to the west of Ellettsville, there may be observed a plains-like expanse of a few square miles. This is a small part of the basin of Glacial Lake Flatwoods.[2] The area owes its plains-like character to the deposition of lake sediments that now smooth over a somewhat more rugged subsurface. It is probable that some of the flatness is structural in that the Mitchell limestone forms the subsurface rock.

The drainage of this lake basin is now by way of McCormick's Creek to the west fork of White River. Before the present drainage was established the lake had a number of overflow outlets and one of these may be observed in the southeast part of section 1, T9N, R3W. Here the waters overflowed into a tributary valley of Racoon Creek.

Drainage Adjustments. All of the larger stream valleys represented upon the quadrangle were modified to some extent as a result of glacial obstructions to the stream courses. These obstructions are without the limits of the area and the extent to which they resulted in modification of the valleys and stream courses varies considerably within the region.

The most conspicuous case of drainage change is represented in the extreme northwest part of the quadrangle in sections 11 and 14, T9N, R3W. Here streams disappear and farther south emerge as springs in the valley of Raccoon Creek. Field study leads to the conclusion that, prior to the advance of the Illinoian ice, there was surface drainage from the area to the northwest and that subterranean drainage was established beneath the sandstone capped ridges. The deposits of glacial outwash destroyed the existing surface drainage, clogged the subterranean routes and overflow for a time was in progress through a low gap in the ridge. Since glaciation there has been a return to subterranean drainage through re-excavation of old routes or creation of new ones and a new system of surface drainage has been established.[3]

There is a suggestion that Raccoon Creek formerly flowed to the north of Freeman Hill rather than to the south as at present. Freeman Hill, T9N, R3W, section 22, is a bed rock hill, but the flat topped ridge immediately north is composed entirely of outwash materials, no bed rock being exposed in the ravines. At Freeman the stream goes through a relatively narrow rocky gorge. These conditions are very suggestive of drainage derangement. The general statement that these changes of drainage are related to the Illinoian margin is very insufficient and they merit careful investigation.

A case of drainage change almost duplicating that of Raccoon Creek is shown by Bean Blossom Creek in section 4, T9N, R1W. Here the

[2] C. A. Malott, "Handbook of Indiana Geology," pp. 211-215.

[3] A. R. Addington, A Special Case of Drainage Adjustment Near the Illinoian Drift Margin in Southeastern Owen County, Indiana. Proc. Ind. Acad. Sci. 1925. pp. 125-130.

stream passes to the south of a knob-like hill of Riverside sandstone. North of the hill there is a rather wide gap that is filled with terrace materials. It is entirely possible that before the present valley was in a laked condition the stream flowed through the valley depression north of the knob.

Alluvial Terraces. Alluvial terraces are present in all the larger stream valleys of the quadrangle. They are best developed in the valleys of Raccoon, Richland, and Bean Blossom creeks. Low terraces are present in the valleys of Salt and Indian creeks near the points where these streams flow from the quadrangle.

The terraces of Bean Blossom Valley early attracted attention and their origin was suggested by Marsters[4] as due to deltas of incoming streams, a condition not in harmony with the materials of the deposits or with their positions in the valleys. The materials of the terraces are finely stratified silts, some of the stratification being so fine that it is scarcely perceptible to the naked eye. The alluvial terraces of the quadrangle are apparently the result of partial excavation of lake silts that had accumulated in the creek valleys when they were in a ponded condition. When the lake waters were drained away the streams began excavation of materials of the lake flat. The terraces we note today are the erosional remnants of the former existing lake bottom.

The alluvial terraces in the Bloomington quadrangle vary from four feet to 60 feet in height. Those of Bean Blossom Creek average about 40 feet, those on the lower portion of Richland Creek average about 60 feet. Low terraces are found near the margins of the old lake basins. The terraces form conspicuous topographic features of the larger creek valleys.

Rejuvenated Sinks. It is not unreasonable to assume that considerable areas over which the ice advanced were characterized by the presence of numerous sinks of various shapes and sizes. Where the sinks were located in regions of glacial deposition they were in many cases filled with the glacial materials, so that evidence of their previous existence was obliterated. Following the recession of the ice the glacial materials filling the sinks have been removed through underground passages, so that new depressions have appeared in the positions of the older ones. There are those sinks where nearly all or all of the glacial materials have been removed, and there are others where the processes of removal are still in operation. Sinks of this character are located in the northwest part of the quadrangle.

In those situations where the stream valleys were ponded and the terrace filling was sufficient to mantle over the limestone rock of the valley sides, we find sinks whose basins are margined by terrace materials. Sinks of this character are excellently developed in Section 23, T9N, R3W. These sinks differ from those mentioned above merely in the character of the materials margining the depression. There is room for discussion relative to the post glacial or pre-glacial origin of some of the bed-rock depressions.

[4] Proc. Ind. Acad. Sci. 1921, pp. 222-237.

Filled Valleys. It has been stated that all the main valleys of the quadrangle were affected by glacial obstructions and, due to this, it would be inferred that some valley filling would result, but it should be pointed out that relative to the valleys of Bean Blossom and Salt creeks the filled condition is due in part to the overloading of their streams with glacial materials. These streams and their tributaries head upon the glacial drift and during the period of advance and recession of the ice mass abundance of glacial detritus was supplied to them and to their tributary streams, resulting in the building up of the valley floors and the widening of the valley flats.

The valley-fill materials are assorted sands and gravels that in the Bloomington Quadrangle are found below the lake silts. Drill records show a depth of 80 feet of unconsolidated materials in Bean Blossom Valley. Records are not available for Salt Creek Valley in this region, but it is estimated the amount of valley-fill is less than in Bean Blossom Valley.

The rather broad and flat valley bottoms, margined by steep valley walls, in some places surmounted by cliffs of limestone, and the numerous sharp ravines etched in the valley sides, characteristic of Bean Blossom and Salt Creek valleys and their tributaries, form two very conspicuous topographic areas of the quadrangle. This topographic condition is related to glaciation only in so far as glaciation was responsible for the filled valley condition. The topographic details of the valley margins are to be explained by differences in rock characters of the Riverside sandstone and Harrodsburg limestone.

Topographic Features Independent of Glaciation.

Karst of the Bloomington Region. Features characteristic of karst lands are numerous and are excellently illustrated here. Caverns, sinks of various types and stages of development, swallow holes, subterranean streams, and subterranean piracy are all features of a karst region which form a prominent part of our natural laboratory. But little space can be allotted to a discussion of them here.

Caverns. There are approximately 50 caverns situated within a radius of 20 miles of Bloomington. Most of these are located to the west and south of the city, and for the greater part are found in the Mitchell limestone. In comparison with some of the better known caves of the state they are small and are but little more than water-worn channels in the rock.

The entrances to some of them are rather spectacular features and are part of an environment that is more or less of interest to the visitor or pleasure seeker (fig. 4). Some of the entrances are of the mouth type as the accompanying illustration demonstrates; other entrances are sink holes (fig. 5) that perhaps appeal to the imagination less than the yawning mouth entrance.

Without attempting a definite classification, I believe three types of caverns may be pointed out in this region. There is the type that is characterized by extensive room development such as Truitt's cavern. Here large underground cavities are connected by more or less zigzag

Fig. 4—The entrance of Boone Cavern, a typical mouth entrance, located in the northwest part of the quadrangle. Entrances of this type are among the most spectacular to be found on the quadrangle. The dimensions of the entrance are 24 x 7 feet.

Fig. 5—View of a cave entrance at the bottom of a sink hole. It is representative of the sink type of entrance, although the illustration does not show the profile of the sink.

passageways which follow the rock fractures, their zigzag character being a result of the system of rock joints (fig. 6).

There is the tubular type of cavern. Such is devoid of extensive room development. Its passageways follow the bedding planes and joints of the rock. This is characteristic of those caverns found in the Salem limestone. Contributing factors are the relatively uniformly porous character of the rock, its massive character, its thickness, which is much less than the Mitchell limestone, and its less extensively jointed character (fig. 7).

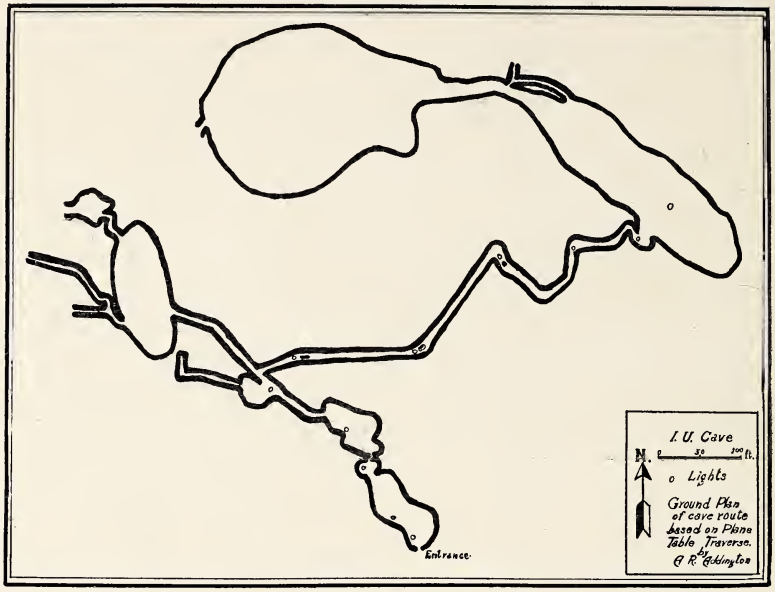

Fig. 6—A ground plan of I. U. Cavern, 5 miles west of Bloomington. It illustrates the type having large rooms. The angular character of the narrow passageways is due to jointing of the rock. The parallel alignment of the large rooms is doubtless a joint controlled phenomenon.

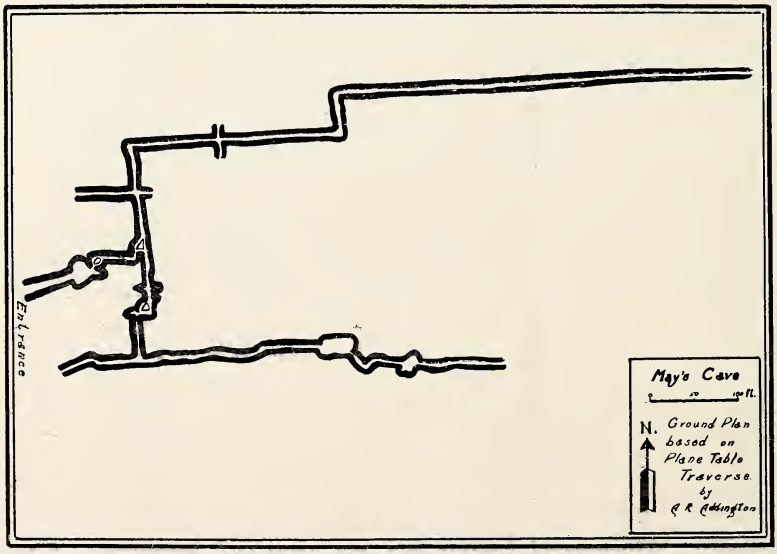

Fig. 7—The tubular type of cavern. In contrast to the type shown in figure 6. it is to be noted there is an absence of extensive room development. The cavern is in the Salem limestone. It is but little more than a rock worn groove.

A common characteristic for the types mentioned above is their greater horizontal extent as compared with their vertical extent. I mention this for purposes of contrast with a third type which has greater vertical extent. This is a well-like cavern, sometimes having a yawning, awe-inspiring, well-like opening that leads to a more or less jug-shaped interior. There are several caverns of this type that are located near the eastern border of the Crawford Upland, a location that is generally characterized by considerable local relief. Exploration of this type of cave does not disclose any horizontal passageway that can be followed. This does not preclude, however, the possibility of such passageways being clogged by weathered detritus from the entrance, thus affording no visible evidence of their existence.

Sinks and Sink Hole Ponds. The margin of the perched limestone plain to the west and south of Bloomington illustrates various stages of sink hole development. In a general way the larger sinks are adjacent to the entrenched valley heads of the plain, and within the larger sinks may be observed younger and smaller depressions. The shapes of the sinks are varied, some are beautifully circular in outline, others star shaped, and others shaped so as to defy description. It may be a mere coincidence, but these features cluster in greater numbers about the bases of the monadnock-like features of the plain.

In some instances the bottoms of the sinks become plugged with clay, either by natural or artificial processes, and a pond then occupies the depression. It is not an uncommon sight to find in close juxtaposition sinks that are ponded and those that are not. A bird's-eye view of a surface dotted with sinks reveals a topography of a peculiar rolling character, with numerous basins separated by undulating ridge-like divides, the monotony of the entire landscape broken here and there by sink hole ponds in the depressions.

Subterranean Piracy. The drainage history associated with the former headwaters of Indian Creek has been discussed by Beede[5] and so does not demand detailed discussion in this paper. By way of review it may be pointed out that Indian Creek formerly flowed as a continuous stream from a point some two miles west of Bloomington until it joined the east fork of White River near Shoals. Its headwaters were situated upon a plain underlaid with the Mitchell limestone, a highly jointed limestone formation. By rejuvenation this limestone plain attained a perched position relative to the valley levels on either side, with the result that subterranean drainage was established and the headwaters of Indian Creek were diverted to valley levels on either side of the limestone platform, thus exemplifying cases of subterranean piracy.

Topographic evidence of these drainage diversions are present today in the form of a valley depression that extends from the position of the former headwaters to the present valley of Indian Creek. Considerable modification of the valley has occurred since the time of the diversion of the headwaters.

[5] J. W. Beede, *The Cycle of Subterranean Drainage as Illustrated on the Bloomington, Indiana, Quadrangle.* Proc. Ind. Acad. Sci. 1910, pp. 91-111.

Limestone Springs. It is an inevitable result in regions where surface streams become subterranean that the streams will ultimately reappear in the form of large springs. Many of these springs are to be found in the valley heads that entrench the limestone plain. Leonard's Springs, Stony Springs, Blair Springs, and the Breeden Spring are but a few of the large limestone springs of the region. Such springs vary widely in volume and almost directly with the precipitation, a condition that indicates rapid transfer of surface waters through the subterranean routes. The waters of such springs are relatively easily contaminated, and due to the character of the rock from which they emerge they cannot be successfully impounded for purposes of municipal supply.

Kirksville Ridge. The Kirksville ridge is the most prominent topographic feature of the south central part of the quadrangle. From selected places on or near its summit, on a clear day, one can see for a distance of 20 miles to the eastward. Views from it are among the best obtainable in the Bloomington region.

As a topographic feature the somewhat extensive axial summit of the Kirksville ridge is the remnant of a peneplain of early Tertiary Age. This was a peneplain of wide extent, but is now represented only by the summits of the higher ridges and hills that reach elevations of 900 feet or more. Corresponding levels are found in Kentucky, Tennessee, Ohio, Pennsylvania, and elsewhere.

It is from the summit of this ridge to the valley levels of tributaries to Clear Creek that the greatest local differences in relief of the region are found; differences amounting to 300 feet or more within one-half mile.

The ridge contains features of interest in the presence of well-like caverns, sandstone rimmed sinks, and parts of a small coal basin.

Late Tertiary Peneplain. From the summit of the Kirksville ridge one may observe long spurs of land of relatively uniform elevation extending in a general easterly direction. The present stream courses are well entrenched below the level of these land masses. The summits of these ridges represent a partially completed peneplain of probable late Tertiary Age. The elevation is approximately 700-760 or about 200 feet below the level of the remnants of the older peneplain surface. Similar elevation relations are found in other areas, notably in Brown County, where the subsurface rocks are of relatively uniform lithologic characters. Consequently, the two levels form a topographic condition that is not to be explained on basis of lithologic difference of the subsurface rocks.

Minor Topographic Features. It is true that the topographic condition of the entire region is more or less associated with the development of the present cycle of erosion; but there are hosts of minor surface details that came into existence during and following the last rejuvenation of the region. These features are for the most part the present valley depressions, with their intricate detail of marginal ravines, cliff exposures, overlapping spurs, valley monadnocks, entrenched

meanders, cascades and rapids. Some of these features, such as the cliff exposure at Cedar Cliffs, the entrenched and meandering character of Clear Creek Valley, and the small cascades north of Bloomington, form rather conspicuous details of the landscape. They are but temporary features, and their existence connotes the ever changing contour of the earth's surface. Tennyson has so beautifully expressed these changes as follows:

"The hills are shadows, and they flow
From form to form, and nothing stands;
They melt like mist, the solid lands,
Like clouds they shape themselves and go."

Summary.

The Bloomington Indiana Quadrangle is a plains region characterized by great diversity of topographic forms. The diversity of its surface features is partly the result of its marginal location to the glacial drift, partly the result of the differences in lithological characters of the subsurface rocks, and more directly to the processes of denudation that have operated upon its surface.

The area is especially interesting from the standpoint of the number and variety of the physiographic problems that it affords. Outstanding in this respect are the features typical of Karst regions.

The present paper does not attempt to completely describe all the topographic features or to explain in minute detail the various stages of their development. Such presentation would in itself form a voluminous piece of work. The writer will be satisfied if he has succeeded in presenting the physiographic background and a brief description of the significant topographic features which are so abundant in the Bloomington Quadrangle region.

LIGHTNING, NATURAL AND ARTIFICIAL.

HARVEY A. ZINSZER, Hanover College.

Lightning is an electrical discharge taking place either between two charged clouds or between a charged cloud and the earth's surface. Arago distinguishes three kinds of lightning: (I) Forked lightning, of ordinary occurrence; (II) sheet lightning, probably the reflection of distant forked lightning hidden from view by intervening clouds or by the horizon; (III) globular lightning, usually described as a luminous ball which travels slowly and finally bursts with explosive violence. The latter is comparatively rare but must be admitted as a real phenomenon; it has occasionally been imitated on a small scale in the laboratory.

Occurrence of Electricity in Clouds. It has been suggested that the electric charge in clouds originates from evaporation proceeding from the earth's surface. It may also arise from the friction between solid and liquid particles suspended in the air or between these and the earth's surface; or, again, from friction between masses of air at different temperatures. That bodies even in close proximity frequently possess slight differences of potential can easily be shown by means of Kelvin's electric doubler.

Thompson[1] describes the mechanism of the accumulated charge in a cloud by assuming that minute water particles floating in the air fall by gravity and unite. Thus should eight similar droplets unite into one the radius of the latter will be twice that of any of the original eight; and its capacity will, therefore, be twice that of one of its components. Hence its electrical potential must be four times as great as that of one of its components. Furthermore, the electrification at the lower surface of a cloud consisting largely of such spheroids will constantly increase and induce on the surface of the earth beneath it a charge of the opposite kind.

Steady Strain and Disruptive Discharge. Sir Oliver Lodge[2] distinguishes between two distinct types of atmospheric discharge. Thus, if a thunder cloud extending over part of the earth becomes gradually charged, or if a charged cloud moves gradually over a particular spot, the air between the cloud and the earth experiences a steadily increasing electric stress under which points will tend to discharge better than blunt objects; and they are more likely to receive the lightning spark when it occurs. However, if a cloud is suddenly charged by receiving a lightning spark from an adjacent cloud, a pointed rod under it has

[1] S. P. Thompson, "Elementary Lessons in Electricity and Magnetism." (Macmillan) 1918.

[2] Jour. Inst. Elec. Engrs., *XVIII*, 80.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

had no opportunity for preparatory action and is no more likely to take the discharge than a blunt conductor of equal height.

These two cases have been imitated in the laboratory by arranging the apparatus as shown in figures 1 and 2. The former illustrates the condition for a steady strain while the latter represents the condition for a disruptive discharge.

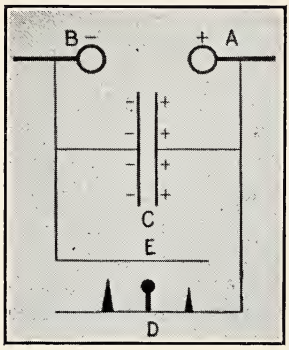

Fig. 1—Condition of Steady Strain.

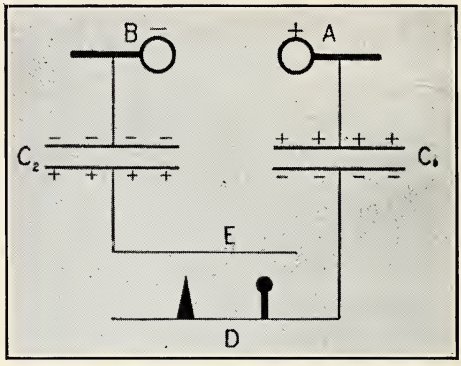

Fig. 2—Condition of Sudden Strain.

A flat piece of tin, E, is connected to one terminal of an electrostatic generator, while several points of varying height and a ball are connected to the opposite terminal of the generator. Capacities are arranged as indicated in the figures. When thus arranged the space between E and D in figure 1 will be in a condition for a steady strain, and either point is more likely to be struck than the round conductor. On the other hand, in figure 2, the space between E and D is in a condition for a disruptive discharge which will occur whenever a spark

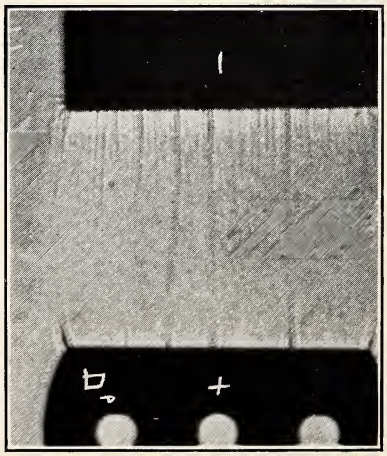

Fig. 3—Field due to a Steady Strain.

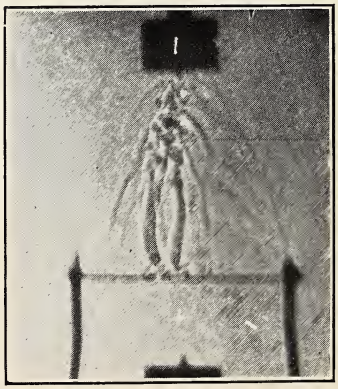

Fig. 4—A disruptive Discharge.

passes between the terminals of the generator. Under the latter condition the resultant discharge across E and D will occur as frequently between the ball and the plate as between the point and the plate. Instantaneous views of such discharges were obtained by the writer[3] and appear in figures 3 and 4. The former represents a steady discharge between sharp parallel edges, while the latter represents a sudden discharge between an horizontal wire and a point.

Natural Lightning. Figure 5, by Brown,[4] shows a natural forked discharge of the disruptive type, while figure 6 shows the effect of such a discharge. The tree in the latter figure is a large locust standing near the entrance to the library at Hanover College. The library is located on a level bluff about 400 feet above the Ohio River. Close scrutiny of the picture will reveal a number of wires fastened to the tree. An interesting fact about this particular bolt is that its course of destruction continued down the trunk of the tree to the very place where the wires are attached. Two responsible witnesses of this crash testify that so great was the quantity of electricity involved that the various chips and splinters torn loose from the tree emitted light flashes of their own as they struck the earth.

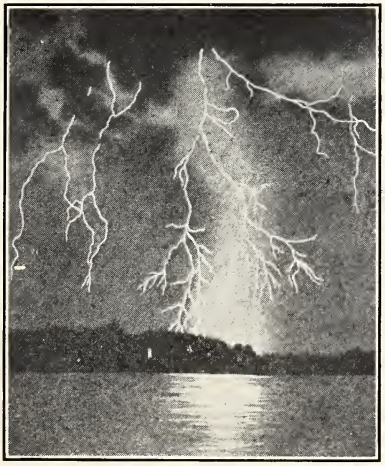

Fig. 5—Natural Lightning.

Figure 7, by Peek,[5] shows a test oscillogram of a two and a half million volt lightning bolt striking a transmission line of the Pennsylvania Power and Light Company. This is the first record of the voltage of a lightning surge obtained in this country by the cathode ray oscillograph. The record shows that the duration of the surge was 40 microseconds.

[3] Phil. Mag. *5*, 1098, (1928) ; Proc. Ind. Acad. Sci. *37*, 197, (1927).

[4] Millikan, Gale and Edwards, "First Course in Physics for Colleges," (Ginn & Co.) 1928.

[5] General Electric Review *31*, 467, (1928) ; *31*, 404, (1928).

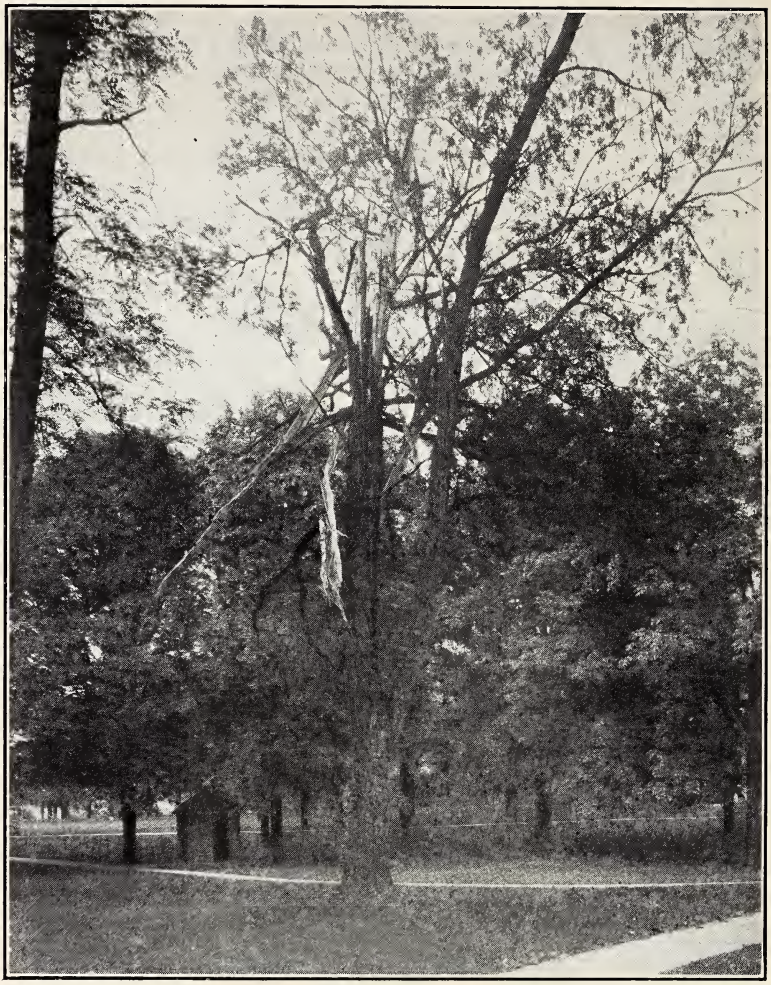

Fig. 6—Result of a Natural Discharge.

Fig. 7—Oscillogram of Lightning Surge.

Artificial Lightning. Apart from the study of its mechanism, the most important factors concerning lightning are the ideas of protection and utilization. The first suggestion for the protection of property from destruction by lightning was made by Franklin in 1749. Later, Lodge[6] made a number of investigations which resulted in his paper on "Lightning and Its Protectors." Investigations of the effects of lightning, particularly upon power transmission lines, where a single discharge may cause considerable damage to valuable machinery, are constantly being conducted in various laboratories where the natural phenomenon is simulated by means of static generators of enormous voltage and frequency and the characteristics of the wave disturbance are studied by means of improved cathode ray oscillographs.[7]

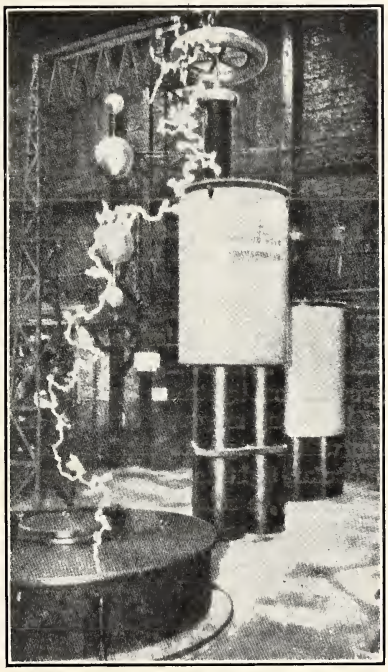

Fig. 8—Artificial Lightning.

A view of a giant man-made lightning bolt of several million volts jumping an irregular arc of 18 feet appears in figure 8. This artificial discharge was produced in the laboratory of the General Electric Company at Pittsfield, and it is by means of such contrivances that engineers can test the efficiency of circuit breakers, strain insulators and other devices designed to safeguard power lines.

Figure 9, by George and Oplinger of the Purdue University Engineering Experiment Station, shows a 100,000-volt, high-current discharge

[6] Loc. cit.

[7] General Electric Review *28*, 622, (1925).

Fig. 9—100,000-Volt High-Current Discharge.
(By courtesy of R. H. George)

from a point to a metal pan containing a solution of salt water. Although the resistance of the salt solution is relatively low, the RI drop is so great as to cause it to flash over. This emphasizes the necessity for low resistance grounds on lightning protection apparatus, and explains why strokes of lightning may run over the surface of the ground where it strikes. The writer suggests that the conditions for the production of natural globular lightning are similar to those which prevailed in this picture, namely, a relatively low conducting surface, more or less equally distributed, and an enormous potential difference.

THE THERMIONIC VOLTMETER AS APPLIED TO HIGH FREQUENCY MEASUREMENTS.

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Numerous articles have appeared in the last few years announcing types of vacuum tube voltmeters to be used in high frequency electrical measurements. Such a voltmeter should have the following characteristics: (a) it should be entirely independent of frequency; (b) it should not absorb power from the measuring circuit; (c) it should hold a calibration over a considerable period; (d) it should not require too much auxiliary equipment; (e) it should have a wide range in voltage, say from 0 to 100 volts; and (f) it should not change materially the constants of the circuit to which it is applied.

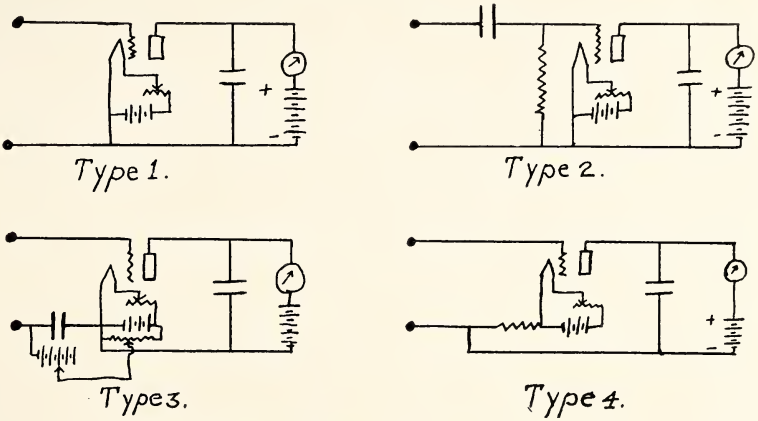

Fig. 1—Common Types of Thermionic Voltmeter.

The various types could be classified under four heads as in figure 1, namely, (1) direct deflection, readings directly proportional to voltage; (2) leaky grid or inverse, readings inversely proportional to voltage; (3) slide back, voltage measured by amount of grid bias to compensate for applied high frequency voltage; (4) reflex, a high range voltmeter having an automatic bias voltage proportional to input voltage.

The present discussion is limited to the two most widely used types, the direct deflection and the "leaky grid" or inverse type. As a further limitation only the application of such instruments to radio frequency circuits will be considered.

There is an abundance of information available in the literature concerning the construction, characteristics, and calibration of thermionic

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

voltmeters. Very few articles[1] can be found dealing directly with the application of this device to actual measurements in high frequency circuits. The present paper is the result of an attempt to measure inductance, capacity, resistance, frequency and impedance at frequencies from 600 to 1,200 kilocycles. Voltages used varied from 0 to 80 R. M. S. volts and currents from 20 to 125 milliamperes.

A general method of procedure with such an instrument is to measure the voltage across the terminals of the impedance, (a capacity, resistance, inductance, etc.). Knowing the frequency and current, from the relations $E=ZI$, $Z=\sqrt{R^2+X^2}$, and $X=2\pi fLI$ or $\frac{1}{2\pi fC}$, R, L, and C may be determined. This method is accurate provided the voltages are low. Consequently the currents must be small through the impedances. Since small high frequency currents, less than ten milliamperes, are difficult to measure except with thermo-junctions and sensitive galvanometers, this method is practical only for small resistances, small inductances, or large condensers. (The voltage across a 398 mmf. condenser at 750 K. C. is approximately 26.6 volts with a current of 0.050 amp.). If a known small inductance say about 8 microhenries is placed in a high frequency circuit and the voltage measured across the inductance, from the relation $E=2\pi fLI$, f may be determined or the voltmeter could be calibrated directly in kilocycles at a constant current value. Either type 1 or type 2 voltmeter may be used for these measurements *provided the voltage measured does not exceed 1.8 volts for type 1, and 5.5-6 volts for type 2.* If these limits are exceeded the voltmeter input circuit absorbs enough power to change the current appreciably in the measuring resonant circuit. Figure 2 shows such a measuring circuit.

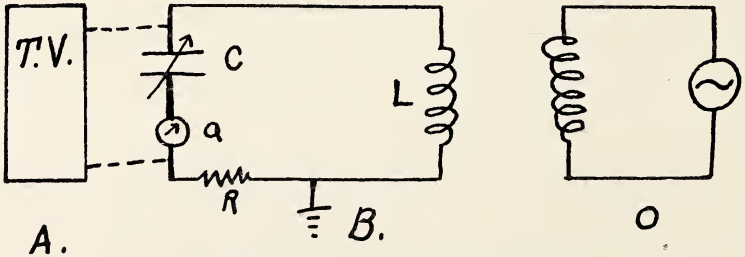

Fig. 2—Simple Measuring Circuit for Thermionic Voltmeter.

In this figure the oscillator O generates the high frequency current. The measuring circuit B is coupled loosely to O and the thermionic voltmeter A is connected across C, R, or L as the case requires. The voltmeter input circuit contains capacity varying from 4-20 mmf. and an effective resistance of 0.2-8 ohms, depending upon the circuit and type of tube used. These factors must be taken into consideration in making any accurate determination with such an instrument.

[1] See Bibliography.

We shall next consider a special method developed in this study for measuring higher voltages (0-80 volts), such as would be obtained using from 20-100 milliamperes at 600-1,200 kilocycles with ordinary radio coils and condensers.

The circuits used are shown in figure 3.

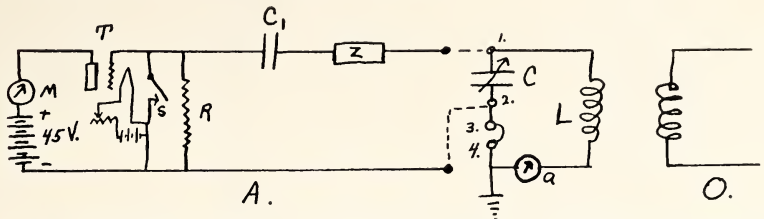

Fig. 3—Measuring Circuit for Multiplying Voltmeter, Arranged for Substitution Methods.

An inverse voltmeter (A) was used, having the following constants: M a (0-1) milliammeter; T, a UV-201 A tube; C, a 0.2 mf. mica insulated Western Electric condenser; S, a short circuiting switch to adjust filament to initial maximum reading; R, a 5 meg-ohm resistance; Z, an impedance 160,000 ohms approximately; C_1 is a variable air condenser; L, a low loss pickup coil; and O, a vacuum tube high frequency generator. The circuit was arranged with mercury contact points at 1, 2, 3 and 4 so that quick substitution of coils, condensers and resistances could be made. The purpose of the impedance Z in the input circuit was to multiply the reading of the voltmeter. A standard cartridge resistance of 500,000 ohms was first used for Z. With this resistance about a thousand readings and calculations were made to determine the multiplying factor M of such a voltmeter. Over a range of 600 to 1,200 K. C., M varied from 12.27 to 16.3, the increase in M being directly proportional to frequency. This suggested that the capacity of the ends of the cartridge and the holder was affecting the results. The resistance core was then removed entirely and the voltmeter still had a multiplying factor of about 8.

Since the impedance of 1 mmf. at 1,000 K. C. is about 160,000 ohms and since the capacity of the ends of such a cartridge is of this same order of magnitude it can easily be seen why such a voltmeter would have a varying multiplying factor. (An additional study is being made of this phenomenon.)

In applying such a voltmeter the following methods were used.

The voltage was measured across a standard coil and then across an unknown coil. If the frequency and current is kept constant by variation of coupling, and tuning to resonance, $E:E_x = L:L_x$ or with condensers $E:E_x = C_x:C$ C_x may be determined in terms of E, E_x and L. This method assumes that a curve has been made for the value of M against frequency.

The voltage across an unknown and a known coil may be made the same by varying the current through the circuit through a change of coupling. Then if f is kept constant $L_x:L = I:I_x$ or $C_x:C = I_x:I$. This method eliminates the actual value of voltage and M need not be known.

The following table gives some results obtained by these methods in comparison to other standard methods.

TABLE I. Value of Inductance and Capacity from the Voltmeter Method as Compared with Other Methods.

Inductance in Microhenries

E constant	I constant	$L=E/2\pi fI$	Wavemeter	Calculated
48.9	48.8	49.7	47.5	....
96.8	98.7	97.9	99.0	98.8
19.0	....	20.6	20.7	21.3

Capacity in Microfarads

E constant	I constant	Wavemeter	Bridge Measure
395	398	410	410
279	280	274	275
314	313	322	320

Frequency 750 K. C. Currents 30-100 milliamperes

During the course of this work many interesting and unexplained phenomena concerning high frequency measurements have come to light. It is not our purpose here to dwell at length on all the possibilities of such an instrument.

The most important conclusions that can be drawn are that for correct measurement: (1) The impressed voltages cause no appreciable current in the grid circuit of the voltmeter. (2) The negative filament terminal must be grounded. (3) The effective resistance and capacity of the voltmeter must be considered. (4) The grid must in no way be insulated from the filament by a high resistance grid return circuit. (5) Inductive effects should be avoided by shielding and short voltmeter leads. (6) At present there is no single type of thermionic voltmeter applicable to all conditions and voltages. (7) Application to audio frequency circuits is more easily accomplished because of greater power and current values and lower voltages.

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THE EFFECT OF VARIATIONS OF THE FORCE FUNCTION UPON ORBITS OF LEAST ACTION.

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A unique episode in the history of astronomy resulted from a hypothesis of Leverrier. To account for the motion of the perihelion of Mercury he supposed there was a small planet (Vulcan) rotating between Mercury and the sun. As late as 1905 the opinion was tentatively accepted by many astronomers that the irregularities of motion were due to the presence in that region of a ring of meteoric substance. In the case of the analogous erraticism of the moon's motion around the earth Hall tested the effect of assuming a gravitational force μ/r^2+e, $e \doteq 0$, instead of Sir Isaac Newton's function μ/r^2. E. W. Brown showed (1903) that this alteration led to errors. In 1905 Einstein published the first of his work on relativity and somewhat later an equation of the orbit of a single planet which was soon verified for the case of Mercury.

The following postulates, which are probably the simplest possible, suffice for the present paper and we are led to an orbital equation of a form which includes that of Einstein as a special instance, although the postulates do not involve us with questions of relativity.

(a) Space is euclidian. Thus the squared element of (plane) arc is $ds^2=dx^2+dy^2$.

(b) A particle moving in a plane under the action of a central force (and no other influences except an initial velocity) moves according to the principle of least action.

(c) The force of attraction between a planet and the sun is of the form $\mu/(r^2+\alpha r+\beta)$, r being the distance and α, β infinitesimals.

I. **Least action in a plane.** If a particle Q is projected from a point A, in a plane M, with an initial velocity v_0 and is attracted toward a fixed point O in M by a force P its motion is such that the action integral $\int v ds$ is a minimum. If m is the mass, O the cartesian origin and Q the point (x, y) the equations of motion are,

$$(1) \qquad m\ddot{x}=-Px/r,\ m\ddot{y}=-Py/r,\ (r=OQ)$$

If we multiply these equations by $2\dot{x}$, $2\dot{y}$ respectively and add we obtain, after integrating once,

$$v^2=-2\int F dr+b,\ (F=P/m,\ v=\dot{s}).$$

Taking for initial conditions $v=v_0$ when (r, θ) is (r_0, θ_0) and indicating by $\int_0$ that the initial coordinates are to be substituted after the integration, we obtain,

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

$$(2) \qquad b = v_0^2 + 2\int_0 F dr,$$

$$\int v ds = \int_{\theta_1}^{\theta_2} \sqrt{-2\int F dr + 2\int_0 F dr + v_0^2} \quad \sqrt{r^2 + \left(\frac{dr}{d\theta}\right)^2} \quad d\theta.$$

The orbit of the particle is an extremal[1] of this integral.

If we abbreviate as follows:

$$\int v ds = \int_{\theta_1}^{\theta_2} f(\theta, r, r_1) d\theta, \ (r_1 = dr/d\theta),$$

Euler's equation for extremal curves is

$$(3) \qquad f_r - \frac{d}{d\theta} f_{r^1} = 0,$$

and since f is explicitly free from θ the calculus of variations gives at once the first integral of (3),

$$-\frac{r^2}{(r^2+r^{12})^{\frac{1}{2}}}\left(-2\int F dr + b\right)^{\frac{1}{2}} = C.$$

Substitution of $u = 1/r$, $p = du/d\theta$, rationalization and differentiation once with respect to θ give the known form,

$$(4) \qquad \frac{d^2u}{d\theta^2} + u = \frac{1}{C^2u^2} F\left(\frac{1}{u}\right).$$

This is the equation for extremals of the type which is simplest with reference to the theory of differential equations. It is immediately integrable in the form,

$$(5) \qquad \left(\frac{du}{d\theta}\right)^2 = 2\int \left[\frac{1}{C^2u^2} F\left(\frac{1}{u}\right) - u\right] du + d,$$

and completely integrable in an explicit form involving quadratures.

II. Variations from the Newtonian law of gravitational attraction.

We now assume,

$$(6) \qquad F = \mu/(r^2 + \alpha r + \beta),$$

the numbers α, β being arbitrary but infinitesimal.

From (4),

$$(7) \qquad \frac{d^2u}{d\theta^2} + u = \frac{\mu/C^2}{\beta u^2 + \alpha u + 1}.$$

We write $C = 1$ leaving μ arbitrary. The general solution of (7) with the right hand side replaced by a constant K, is

$$u = A \sin\theta + B \cos\theta + K,$$

A, B being constants of integration, hence any integral curve of (7) is infinitesimally consecutive to a conic.

If we divide numerator by denominator on the right hand side of (7) and neglect, as higher infinitesimals, expressions of orders >2 in α, β we have, after integrating once,

$$(8) \qquad \left(\frac{du}{d\theta}\right)^2 = 2\mu[ku^5 + lu^4 + mu^3 + nu^2 + u + d], \ (= 2\mu U),$$

[1]Bolza, *Lectures on the Calculus of Variations* (1904).

where,

$$k = {}^1/_5\beta^2,\ l = \tfrac{1}{2}\alpha\beta,\ m = \tfrac{1}{3}(\alpha^2 - \beta),\ n = -\tfrac{1}{2}(\alpha + \mu^{-1}).$$

There results,

$$\sqrt{2\mu}(\theta + c) = \int du/\sqrt{U}.$$

This is in the form of a hyperelliptic integral but since terms in k, l, m are infinitesimal it can be evaluated in finite form. In fact,

$$\int du/\sqrt{U} = \int V^{-\frac{1}{2}}du - \tfrac{1}{2}\int V^{-\frac{3}{2}}(ku^5 + lu^4 + mu^3)du + \frac{3m^2}{8}\int V^{-\frac{5}{2}}u^6 du,$$

where,

$$V = nu^2 + u + d.$$

The method of integration by parts may be applied to each integral. If, as ordinarily, we neglect all expressions of order >1 in α, β and assume $u = Kx$, K being a constant whose value is determined when the linear unit is chosen then (8) becomes [2],

$$(9) \qquad \left(\frac{dx}{d\theta}\right)^2 = -\tfrac{2}{3}\beta K\mu x^3 - (\alpha\mu + 1)x^2 + \frac{2\mu}{K}x + \frac{2\mu d}{K^2}.$$

Choose K according to the units employed and

$$\mu = K\lambda,\ d = \tfrac{1}{2}(E^2 - 1)K\lambda,\ \alpha = 0,\ \beta = -3/K^2\lambda,$$

and (9) becomes,

$$(10) \qquad \left(\frac{dx}{d\theta}\right)^2 = 2x^3 - x^2 + 2\lambda x - \lambda^2(1 - E^2).$$

Now (10) is identical with Einstein's equation for the orbit of a single planet about the sun, M being the mass of the sun, a and E being respectively the major semi-axis and the eccentricity, and,

$$x = M/r,\ \lambda = M/a(1 - E^2).$$

For the planet Mercury the values in terms of Eddington units are

$$M = 1.45,\ a = 5.8.10^7,\ E = 0.206,\ \lambda = 2.6.10^{-8}.$$

It has been verified previously that the erratic advance of the perihelion of Mercury is in conformity with the equation (10). The erraticism of the motion of Venus has been explained by (10), (Eddington, loc. cit.) and probably may be accounted for more accurately by (8).

We have therefore developed the verified theory of the motion of planets without the intervention of relativity or of non-euclidian hypotheses, assuming only the principle of least action and a law of attraction (6) which differs infinitesimally from that of Newton.

[2] Eddington, *The Mathematical Theory of Relativity* (1923), p. 86.

A HELICAL BRASS SPRING WITH CONSTANT PITCH ANGLE.

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Theoretical deductions made relating to the period of helical springs are based upon the assumption that the pitch angle (angle between the wire and a horizontal plane) is the same for all parts of the spring. If a long light spring is suspended by one end, the above condition is far from being true since the top turns will be stretched far apart due to the weight of the spring and the bottom ones will not be stretched at all. Springs can be so constructed that they will hang with their coils equally spaced. This paper presents the performance of a brass spring so corrected. The following simple method was used to correct the spring: Fasten one end of a helical spring to a rigid support so that it hangs vertically. Extend the spring using weights attached to the bottom end. Extend the spring enough to give the bottom turns a very small permanent set. The permanent set given to the coils above the bottom one will be proportional to the weight of the spring which hangs below the coils considered. If the ends are now reversed, the spring will hang with the coils equally spaced (pitch angle constant).

The theory[1] is as follows: Let $d\rho$ be the permanent extension of any length dx when the spring is hanging vertically just after it has received its permanent set and after the load has been removed. Assume that the permanent set is proportional to the excess stretching force P so that $P \Big/ \frac{d\rho}{dx} = K$ a constant. Then $\frac{d\rho}{dx} = \frac{P}{K}$ = permanent set per unit length at point x. Let the origin be taken at the top, the length of the unstretched spring be L and its weight per unit length be w. Then $\frac{d\rho}{dx} = \frac{W}{K}(l-x)$.

If the ends of the spring be reversed, the stretch of the spring per unit length at any point x due to its own weight will be added to the permanent stretch per unit length for the same point on the spring. It is to be shown that the sum of these two stretches will be constant for any position x.

Let the stretch per unit length due to the spring's own weight be

$$\frac{d\rho_1}{dx_1} = \frac{W}{K}(l-x_1)$$

then

$$\frac{d\rho}{dx} + \frac{d\rho_1}{dx_1} = \frac{W}{K}(l-x+l-x_1).$$

The position x is the same on the spring as the position when the spring is inverted.

[1] Suggested by A. P. Poorman, Department of Applied Mechanics, Purdue University.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

Therefore substitute $x_1 = l - x$ and it will give

$$\frac{d\rho}{dx} + \frac{d\rho_1}{dx_1} = \frac{W}{K} = l \text{ a constant, which was to have been proved.}$$

Experiments were performed to see if this were true and if such a spring were better than one not corrected. A spring made of brass, was corrected as above directed. When it was suspended from the end which was given the least permanent set, it hung with the coils all equally spaced according to theory.

Extensions, h, for an increment m of 100 grams added to the load m were taken for different loads and the periods T for each load were measured with a stop watch. Similar data were obtained with the spring inverted. The following table shows that the extensions in the two cases were approximately the same. The times of oscillation, however, were quite different as expected. The calculated values of time from $T = 2\pi\sqrt{\left(M + \frac{mo}{3}\right)\frac{h}{mg}}$ show that the spring with coils equally spaced was much better. Errors of measurements are less than one-half of one per cent.

TABLE I. Coils Equally Spaced

M = 381.5 gms.

Load M.gms.	h/m cm/gm	Oscillations No.	Time Calc. Sec.	Time Obs. Sec.	Error Sec.
00		406		374.8	
100	0.13810	321	360.8	372.2	11.4
200	0.13810	273	367.0	373.6	6.6
300	0.13800	242	373.6	376.0	2.4
400	0.13795	218	373.4	375.2	1.8
500	0.13790	200	373.2	374.4	1.2

TABLE II. Coils Unequally Spaced

0		406		378.6	
100	0.1378	321	360.1	374.6	14.5
200	0.1381	273	367.0	375.2	8.2
300	0.1380	242	373.6	377.0	3.4
400	0.1380	218	373.4	376.0	2.6
500	0.1380	200	373.4	375.4	2.0

TABLE III. Showing the Difference in the Time of Oscillation

Load M (gms.)	No. osc.	Time Pitch Ang. const.	Time Pitch Ang. varying	Difference of times
0	406	374.8 sec.	378.6 sec.	4.6 sec.
100	321	372.2 sec.	374.6 sec.	2.4 sec.
200	273	373.6 sec.	375.2 sec.	1.6 sec.
300	242	376.0 sec.	377.0 sec.	1.0 sec.
400	218	375.2 sec.	376.0 sec.	0.8 sec.
500	200	374.4 sec.	375.4 sec.	1.0 sec.

POLARIZATION OF RADIO WAVES.

R. R. RAMSEY and J. J. BRADY, Indiana University.

Electromagnetic waves or radio waves are usually transmitted from a vertical antenna, which is a vertical wire of perhaps a hundred feet or more in height. To increase the capacity the wire is usually connected to a "flat top," which is a number of horizontal wires. The field radiated from a vertical wire consists of an electric field in the vertical direction and a magnetic field at right angles to the electric field.

Such a field is said to be polarized in the vertical direction. In order to receive such polarized waves one must use a vertical receiving antenna or a vertical loop aerial, the plane of the loop being the direction of propagation of the wave. It is well known that if a loop aerial is turned at right angles about a vertical axis the signal can be made so weak it cannot be received. In this case the wave is perpendicular to the plane of the loop. If the loop is turned about a horizontal axis until the plane of the loop is horizontal the signal will be cut out because the loop is perpendicular to the plane of polarization of the wave. The plane of the coil must be parallel to the plane of polarization of the wave to receive the signal with greatest intensity. Instead of a loop aerial an antenna aerial might be used. When the antenna is in the plane of polarization and perpendicular to the direction of propagation the signal is the most intense. Thus, a vertical wire antenna will receive from a vertical transmitting antenna.

The first measurements of intensity were made by Austin (Bull. Bur. Stands. *7*, 315, [1911].) The measurements were made on distant transmitting stations using relatively long waves and low frequency, such as were then used in trans-Atlantic transmission. The measurements indicated that the waves were vertically polarized. Similar results were obtained by Smith-Rose and Barfield (Roy. Soc. Proc. *107*, 587 [1925]), using frequencies as high as 677 kilocycles, 443 meters wave length.

G. W. Picard (Inst. Rad. Eng. *14*, 205 [1926]) was the first to investigate the shorter wave lengths. A wooden tower was built on a level flat which was free from overhead wires and trees. On this tower a linear Hertzian oscillator or antenna was mounted in a universal joint so that this aerial could be rotated into all directions. A superhetrodyne receiver was used to measure the value of the signals received in the various planes. Picard found that in the daytime, for all frequencies under one or two megacycles (300 to 150 meters wave length), the maximum signal was received with the antenna vertical. A minimum was found with the antenna horizontal. Surprising results were obtained from stations which were operated on the amateur bands of 3.5 to 4 and 7 to 8 megacycles (85 to 75 and 42.8 to 37.6 meters). These stations

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

were of the antenna ground type so that the wave left the transmitter vertically polarized. The ratio of the horizontal to vertical field was at times as large as three or four to one. These measurements indicated that there was a difference between short waves and long waves. Short waves sent vertically polarized may arrive horizontally polarized. The distances from transmitter to receiver were fifty or more miles.

To try the effect of waves sent horizontally polarized a special transmitter was erected at Schenectady, N. Y., which transmitted horizontally polarized waves. These were received at Seabrook Beach, New Hampshire. At 790 kilocycles (380 meters) the received signals were predominantly vertically polarized. The average vertical to horizontal was 10:1. Similar tests were made at 3.75 megacycles (80 meters). The horizontal electric vector was found to be over twice that of the vertical vector regardless of whether the transmitter was horizontal or vertical. E. F. W. Alexanderson (Trans. Am. Inst. Elec. Eng. *45*, 636 [1926]) states that he has found that short waves have their plane of polarization rotated and at times there was circular polarization. He shows a mechanical model to illustrate the circular polarization, but the details of the experiments are very meager.

The present experiments were conducted to see if there was any change of the plane of polarization near the transmitting station. The frequency selected was 30 megacycles (10 meters) and all measurements were made at distances less than 70 meters, 7 wave lengths.

The transmitter, which is diagrammed in figure 1, consisted of a loop aerial of a single turn of wire connected to the tubes so as to form a modified Colpitts circuit. Two five-watt tubes were used. The filaments were heated from a filament transformer and the plate supply

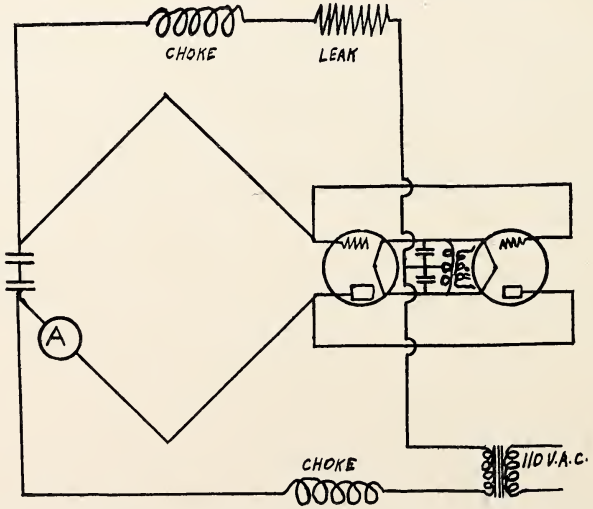

Fig. 1—The transmitter was a square single turn coil of wire. This coil was connected to the tubes as in the diagram. The tubes were mounted on the horizontal axis of the coil. When the coil was rotated the two wires connecting the coil to the tubes were twisted.

was a 500-volt transformer. With A. C. filament and plate supply the power was supplied by a single line of twisted lamp cord, which furnished A. C. at 110 volts. A. C. on the plate served for modulation so that a non-oscillating receiver could be used. Radio frequency choke coils were placed in the lines to prevent the radio current following the 60-cycle supply line. The transmitter was mounted so the coil could be rotated 180° about a horizontal axis. The tubes were mounted in a fixed position in this axis. In rotating the coil the two wires leading to the tubes twisted but were arranged to keep the relative position and area of the coil as near constant as possible. By rotating the coil the transmitted radiation was polarized in the vertical or horizontal plane at will. The receiver diagrammed in figure 2 was mounted in

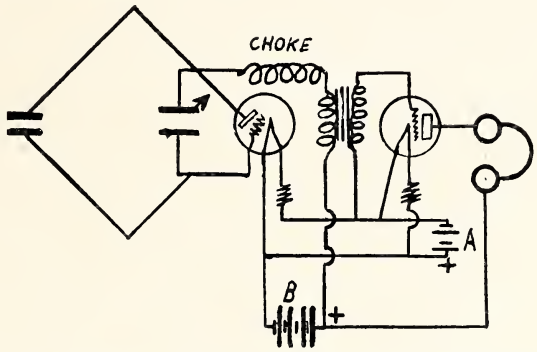

Fig. 2—The receiver consisted of a coil of wire fifty centimeters square connected as in the diagram. The coil was so constructed that it could be rotated from the verticle to the horizontal position.

the same general fashion. U. V. 199 tubes were used and the filament battery was a 4.5-volt C battery and light weight B batteries were used, making the receiver portable. The receiver was mounted on a camera tripod. A single stage audio amplifier was used. A head set was used to judge the intensity. No attempt was made to estimate or measure the intensity of signals; position of maximum and minimum intensity alone were measured.

Transmitter Vertical. With the transmitter vertical the maximum position or the maximum intensity of signals were always with the receiver in vertical plane; that is, maximum intensity was received when the two coils were parallel. The intensity when the coils were at right angles was zero or near zero. There seemed to be no difference in the plane of polarization as the distance was varied from close distances to distances of about 200 feet.

Transmitter Horizontal. With the transmitter sending horizontally polarized waves, when the distance was seven feet, the maximum intensity was received when the receiver was horizontal. A minimum was noticed when receiver was vertical. This minimum was not zero, however. As the distance between transmitter and receiver was increased

maximum signals were received at positions other than the horizontal position. At certain positions the maximum was found with the receiver coil set at 45° with the transmitter. At other positions the intensity was the same regardless of the position of the receiver coil.

Receiver Placed on a Step Ladder. In general there was a difference in the plane of polarization when the receiver was on the ladder from that found at the base of the ladder. This effect was more noticeable at distances of 30 to 40 feet. The effect was not so noticeable at distances of 150 to 200 feet.

Transmitter Placed at 45°. When the plane of polarization was 45° the general effect was the same as when the transmitter was horizontal, but the positions of maximum and minimum were much sharper and easily distinguished. There was the change of position of maximum with distance and at places there was the evidence of circular polarization.

Explanation of Observations. The above observations can be explained if we can assume that the earth is a conductor and that there are currents set up in this conductor at some position below the surface. When the transmitter coil is vertical we can assume the coil to be equivalent to two linear oscillators at right angles to each other, one in the vertical position and the other in a horizontal position in the plane of the coil. This horizontal component, as well as its image in the earth, will not radiate in the direction of the recciver, and thus will have no effect on the receiver. The vertical component will radiate in the plane of the coil along the surface of the earth but will not radiate into the ground below itself and there will be no image and no interference, and the maximum will always be in the vertical. The intensity will decrease regularly with the distance.

With the transmitter at 45° we must assume that we have both a vertical and horizontal component, both of which are at right angles to the line connecting receiver and transmitter.

This horizontal component will cause an image in the earth. Both of these, the longitudinal component of the receiver and its image, will transmit horizontal waves to the receiver. The two will be out of phase and the wave from the image is through the earth traveling at a lower velocity than through the air. These will destructively interfere at points, depending on distance. These two, together with the vertical component, will cause the maximum to vary in position with distance. Maximum will be at 45° at certain points, and at other points the resultant horizontal component will be retarded a quarter wave and circular polarization will be the result.

When the transmitter was horizontal we must assume that there was from some cause, the 60 cycle leads and apparatus perhaps, a small vertical component. The general results were the same as when the transmitter was placed at 45°.

The stepladder indicated that the plane of polarization changed with height and thus the relative phase of the two waves will change. If the receiver is very close to the transmitter the intensity of the di-

rect wave is much greater than that from the image and the effect of the image is not noticed. At distances of 200 feet the change of phase with seven feet elevation will be small and the effect will not be so pronounced as at smaller distances.

It will be noted that if the intensity of the image and transmitter is the same the intensity on the surface of the earth will be zero, provided the image is as far below the surface as the transmitter is above since they are in opposite phase. This assumes that the velocity of both waves are the same.

Transmitter on Metal Roof. The transmitter was then placed on top of the press box of the stadium. The roof is made of metal. In this manner any induced current in the roof will be located at a definite point and the radiation from this image will be transmitted through space to the receiver with the same velocity as that from the coil. With the coil in the vertical plane the maximum received signal was obtained when the receiver was vertical. This was true for all distances. When the transmitter was turned horizontal the maximum signal was still in the vertical plane and a minimum was in the horizontal plane. This is explained by supposing that the transmitter radiated a vertical component in spite of the fact that the coil was rotated to the horizontal. If there had been no vertical component and the intensity from the image was equal to the intensity from the coil itself the intensity in the horizontal should have been zero when the coil is horizontal. The image and coil are out of phase and the distance of both from the receiver are approximately the same. This is true for all except short distances. The roof is about 35 feet above the level of the ball field in the stadium.

There was no indication of rotation of the plane of polarization as was the case with the apparatus on the ground, except when the receiver was brought close to the base of the stadium. Close to the base there was in all probability a component which was transmitted through the concrete. When the transmitter was in the 45° plane the effects were substantially the same as when in the horizontal plane. The reason for this has been explained before.

Proposed Test. To test the theory further it was proposed to place the transmitter above the roof a distance equal to a wave length, then there should be maximum and minimum positions in space. Along the horizontal or at a height equal to the height of the roof and apparatus there should be a minimum signal, zero if there were no vertical component. At heights such as when the line joining receiver and transmitter makes an angle of 30° with the horizontal there should be a maximum of intensity when the receiver is horizontal.

The image is out of phase with the transmitter and the distance from receiver and oscillators differ by a half wave length, making the radiations in phase at the receiver, figure 3. With the apparatus used in the first part this would require a tower some thirty feet high. It was thought that the transmitter could perhaps be raised five meters. So a new transmitter transmitting on a wave length of five meters

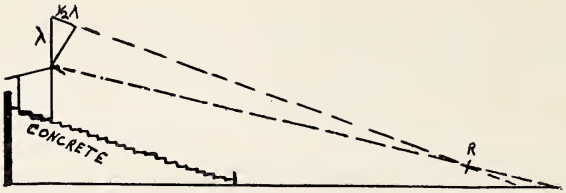

Fig. 3—Diagram showing the transmitter at a height above the roof of the stadium press box. If the lines connecting the receiver at R, makes 30° with the horizontal there will be destructive interference at R.

was started. However, before this was finished some of the essential parts were stolen and the experiments were not tried.

Conclusion: These experiments tend to show experimentally that short electromagnetic waves are polarized the same as light waves, and that the plane of polarization rotates with the rotation of the transmitter, and that if for any reason part of the radiation is horizontally polarized the plane of rotation will vary with distance and at points circular polarization is present: that the earth acts as a conductor, and an image of the transmitter may be present at an indefinite distance below the surface, and that the ground wave seems to have a different velocity from that through space.

These experiments do not explain why short amateur waves which are vertically polarized arrive at the receiver horizontally polarized. This effect must be due to causes remote from the transmitter.

The waves used in this experiment are much shorter than those used by other experimenters.

PHOTOGRAPHY OF SOUND WAVES.

D. L. EATON, Indiana Central College.

Beautiful photographs of sound pulses have been taken by Dr. A. L. Foley and others by the so-called shadow-graph method developed in the Physics Laboratory of Indiana University. These pictures are much superior to those taken by the Schlieren method devised by A. Toepler[1] and used by Mach[2], M. Toepler[3] and Wood.[4] It seems worth while that a method yielding such beautiful results for sound pulses should be tested and further researches made photographically for trains of sound waves. The object of the present research was to determine whether or not the Foley method is applicable to continuous wave trains.

The problem is to get a vibrator of sufficient frequency which will give sound waves of sufficient intensity.

Various methods of generating sound wave trains have been employed. Lodge[5] first showed that the oscillatory discharge of a Leyden jar could be used as a source of audible sound waves. By using sufficiently large inductance and capacity in series with the spark gap he reached a pitch as low as 500. W. Altberg[6] produced short sound waves by the oscillatory current across a spark gap in a circuit containing oil condensers and inductance. The condensers were charged by an induction coil. Altberg succeeded in producing sound waves as short as 1 mm. The waves were measured with a diffraction grating. Duddell[7] showed that an arc light could be made a source of short sound waves by connecting in parallel with the arc an inductance and capacity. The highest vibration rate reached by him was 50,000. Poulson[8] improved this method and got a much higher vibration rate. The principal changes made were the use of copper for the upper electrode, causing the arc to burn in an atmosphere of hydrogen, in a chamber kept cool by running water and steadying the arc by means of a magnetic field. Dieckmann,[9] using a Poulson arc, measured with a grating, sound waves to a vibration rate of 800,000. He got a more nearly steady point source for his sound waves by cutting a notch in the upper and lower electrode, one notch being vertically above the other. C. W. Hewlett[10] devised a mechanical oscillator capable of producing sound waves of frequencies

[1] A. Toepler, Pogg. Ann., *131*, p. 33, N. 180, 1867.
[2] E. Mach, Sitzungsber. d. k. Akad. Wissensch. zu Wien, *98*, p. 1333, 1889.
[3] M. Toepler, Ann. d. Phys., *14*, p. 838, 1904; Ann. d. Phys., *27*, p. 1043, 1908.
[4] R. W. Wood, Phil. Mag., *48*, p. 218, 1899; Phil. Mag., *50*, p. 148, 1900.
[5] Lodge, Nature, *39*, p. 471, 1889.
[6] W. Altberg, Ann. d. Phys. *23*, p. 267, 1907.
[7] Duddell, Electrician, *45*, p. 310, 1900.
[8] Poulson, Electrotchn, *45*, p. 310, 1900.
[9] Dieckmann, Ann. d. Phys., 27, p. 1066, 1908.
[10] Hewlett, Phys. Rev., 17, p. 257, 1921.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

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up to 30,000. In this oscillator a light, slightly stretched diaphragm was caused to vibrate by an oscillating current through two flat (pan cake) coils placed close to the diaphragm, and on either side. The oscillating current was produced by a tube oscillator. Langevin devised a piezoelectric oscillator, based upon the piezoelectric property of quartz crystals. R. W. Boyle[11] used an oscillator of this type. Standing, ultrasonic waves were produced in water, and the nodes and loops were made evident by ridges formed by fine powder settling slowly through the water. Von Mark Holtzman has devised an apparatus which is a modification of the Kundt's tube, which serves as a powerful source of sound waves as short as one centimeter. A small glass tube was continuously rubbed by a belt actuated by pulleys. The rubbing surface of the belt was thick silk and this was kept wet with alcohol.

The sound source first tried in this research was the electric arc with inductance and capacity connected in parallel with it as shown in figure 1.

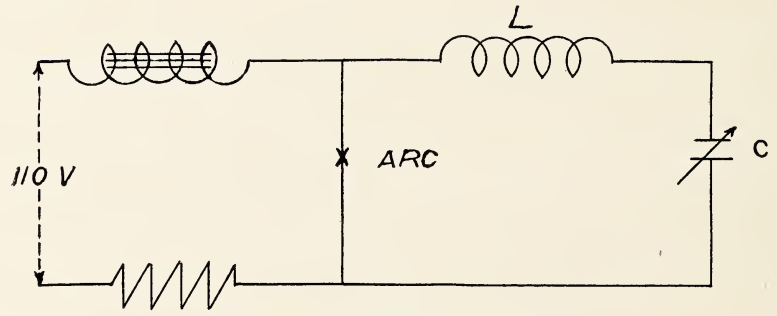

Fig. 1—Diagram of Circuit for singing arc.

The inductance L was continuously variable. The capacity C was a Leeds and Northrup ten-microfarad condenser variable by one microfarad steps. Different sized carbons, cored and solid, were tried; also copper electrodes. Small solid carbons 5/32" seemed to give the largest current in the oscillating circuit. The camera used was the same as described by Dr. A. L. Foley in the Physical Review, November, 1912. The illuminating spark was between magnesium terminals at one end of the camera. The spark was produced by the discharge of Leyden jars, three jars being connected in multiple with each of the jars on the electrostatic machine. The total capacity on each side of the machine was about .006 microfarads.

The photographic plate was at the other end of the camera 2.9 meters from the illuminating spark. The arc which served as a sound source was placed in a light-tight box alongside the camera (fig. 2) communcating with the inside of the camera by an elliptical opening 8.9 cm. x 7.6 cm., the arc being 14 cm. from inside of the camera. The side of the box opposite the arc was cut away so that the light from the arc passed into a rectangular box with V-shaped ends attached to the opening and blackened on the inside. Thus the light was absorbed

[11] R. W. Boyle, Trans. Royal Canadian Soc., p. 90, 1925.

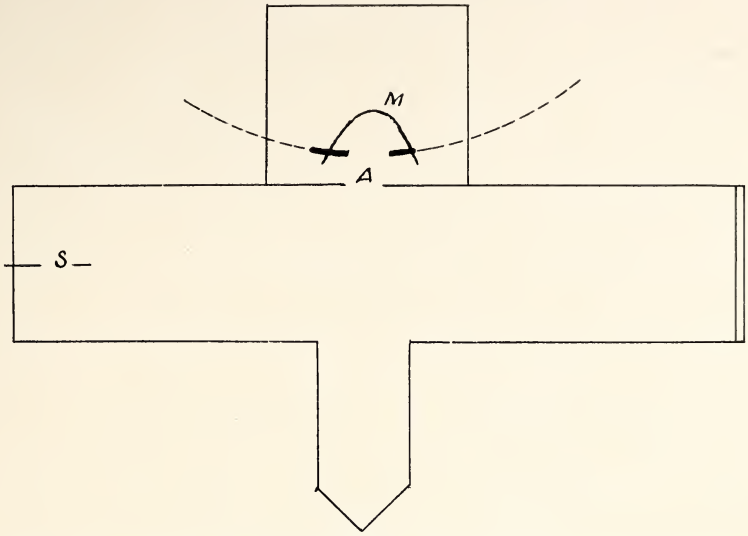

Fig. 2—Diagram of camera. S is the illuminating spark gap, A the arc. A parabolic mirror M was placed back of the arc.

and no noticeable fogging of the plates caused by light from the arc occurred.

In later tests the position of the arc was changed. It was placed close to the large end of a tin funnel 81 cm. long, with elliptical ends 2.5 x .7 cm. and 8.2 x 7.3 cm., respectively. The small end of the funnel projected into the camera and served as a slit source for sound waves.

Two difficulties were encountered. A current of up to six amperes was obtained in the oscillating circuit at audible frequencies, but at frequencies near or above audibility the current in the oscillating circuit was reduced to a small value. Also a wave meter showed a broad wave with a number of pronounced overtones. Apparently the above method will not give pictures of sound wave trains, at least not without some modifications. Some irregular impressions of doubtful origin were found on many of the plates but no plates were obtained with distinct indications of sound wave trains.

The next idea tried out was to increase the intensity of the oscillations of the current through the arc by imposing an alternating current from a tube oscillator on the direct current of the arc. If the direct current I through the arc is equal to or greater than $\sqrt{2}$ times the virtual amperes Iv of the alternating current through the arc, the square of the current through the arc will be a maximum n times per second, n being the frequency of the alternating current. If $I = \sqrt{2}\ I_v$ then the variation of the current through the arc will be from 2 I to O. The resulting expansion and contraction of the gases in the arc will result in a train of sound waves.

The method of producing and imposing the oscillating current on the arc is a modification of that used by Von Konstantin Palaiologus and may be understood from the diagram, figure 3.

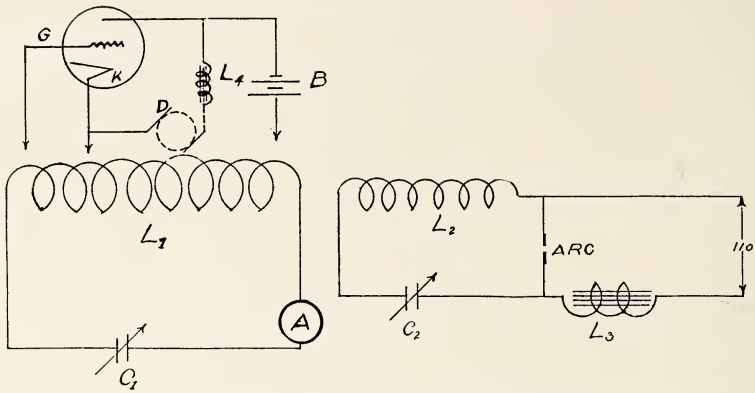

Fig. 3—Diagram of circuit for imposing oscillatory current induced by a tube oscillator on the direct current of an arc.

C_1 and C_2 are made up of Leyden jars and variable oil condensers, the capacity of each being about .018 microfarads. L_1 and L_2 were each about 100 microhenries, the electrical wave length of each circuit thus being about 2,000 meters and the resulting sound waves being .2 cm. First a 5-watt tube was used and later a 150-watt tube. L_3 and L_4 are choke coils—L_3 inductance 1½ henrys, L_4 a large transformer coil. B is a bypass condenser, .0012 microfarad. The plate voltage of the smaller tube was 450; for the larger tube 850 volts. The two circuits were tuned together.

The oscillating current obtained was not as large as expected, the maximum oscillating current through the arc being about two amperes. No definite indications of trains of sound waves were found on any of the plates.

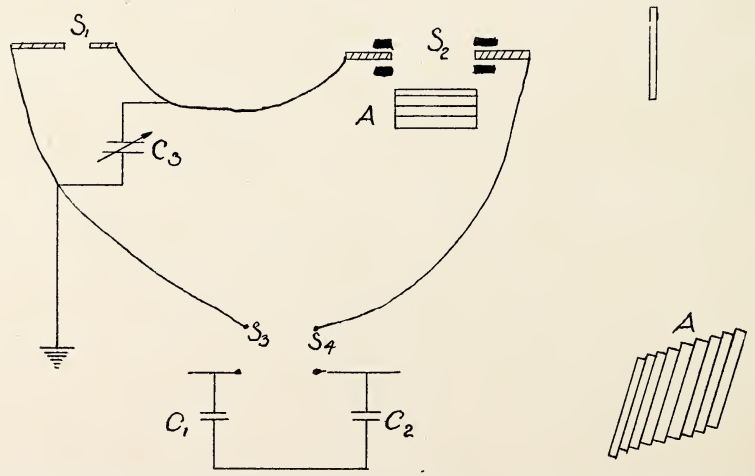

Fig. 4—Diagram of apparatus for producing a sound wave train by reflecting a sound pulse from a series of stops.

A Hewlett oscillator was tried as a source of sound waves. At high frequencies the current through the oscillator was small, the maximum being about .2 of an ampere. No results were obtained.

The last method tried was to produce a train of sound waves by reflection of a sound pulse from a flight of steps made by shearing a pile of selected four-by-five photographic plates. The method may be understood from the diagram, figure 44. S_1 is the illuminating spark gap. S_2, the sound gap, is 2.6 cm. long. S_3, the illuminating gap, was adjustable within wide limits by means of a lever reaching to the plate end of the camera. A is the flight of steps. For relative position of S_2 and A see also figure 6, where the steps are denoted by A and the hard rubber shield for the near terminal of S_2 by *a*. The terminals of the sound gap were platinum. S_3 and S_4 are auxiliary spark gaps at the electrostatic machine. C_1 and C_2 were each composed of one of the regular Leyden jars of the electrostatic machine, together with three other jars connected in parallel. The capacity of C_1 and C_2 were each about .006 microfarads. C_3 was a battery of from six to nine Leyden jars, the capacity of the jars being about .002 microfarads each. The distance of S_2 from S_1 was 1.6 meters. The distance from the plate to S_1 was 2.9 meters. The battery of Leyden jars, C_3, was used to retard the light spark at S_1. The spark could be retarded by increasing the number of jars in C_3, lengthening the spark gap S_1, or shortening the spark gaps S_3 and S_4. The hard rubber shield A helped to prevent the light from the sound spark fogging the plate.

Excellent pictures of sound waves were obtained. In figure 6, may be seen the sound pulse produced by the sound spark and also a series of waves produced by reflection of the pulse from the steps. An increase of speed of the sound waves as they pass through the space near the spark is clearly shown.

Later a plate of hard rubber with a slit .025x4 centimeters was placed above the pile of plates, as shown in figure 5. When each wave struck the slit S the slit became the source of a new sound wave. Thus was produced a train of short sound waves diverging from S as a center. These may be seen in figures 7, 8 and 9.

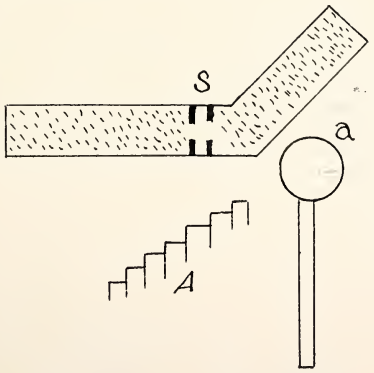

Fig. 5—Method of producing a divergent waves through a slit.

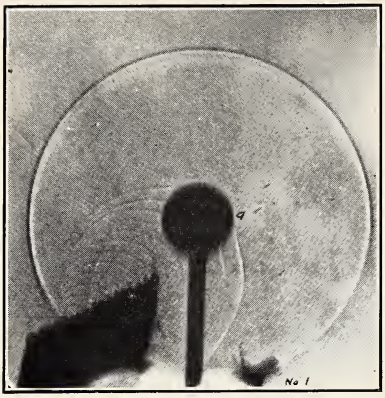

Fig. 6—A sound pulse being reflected from a series of steps. Shows the primary pulse, and a series of waves formed by the reflection from the steps; also shows increase in velocity as sound passes through hot gases formed by the spark.

Fig. 7—The first wavelet, formed by diffraction when primary wavelets strike a slit, diverging from the slit. Diffraction of primary pulse is shown.

On the photographs the wave length is .5 cm. To get the wave length of the sound waves we must divide by ratio of length of camera to distance of sound spark from illuminating spark. This gives .275 cm. as the wave length of the sound waves, corresponding to a frequency of 124,000.

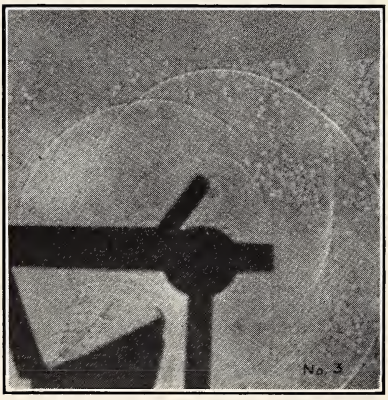

Fig. 8—Shows two wavelets diverging from the slit.

Fig. 9—A still later picture showing a series of waves formed by diffraction through the slit; frequency about 124,000. The wave length is only a little greater than the width of the slit, giving a rather uniform distribution of energy along the wave front.

In figure 7 may be seen the primary sound pulse, the waves produced by reflection from the steps and the first wave produced by diffraction through the slit. In figure 8 there are two waves diverging from the slit and in figure 9 some 17 waves are shown.

The shadow-graph method seems to be well adapted to the photography of sound wave trains; for the intensity of the waves diverging from the slit was exceedingly small. There may be some question as to whether the method will apply so well to a sine wave train or wave trains approximating more closely to such a wave train.

In conclusion I wish to thank Dr. A. L. Foley for proposing the subject, and for his interest and many helpful suggestions during the progress of the work. I wish also to express my appreciation for the assistance given by Dr. R. R. Ramsey, Dr. J. B. Dutcher and Dr. M. E. Hufford.

A CONVENIENT METHOD OF SHOWING ANOMALOUS DISPERSION.

A. W. DICUS, Indiana University.

Anomalous dispersion may be shown by means of a sodium vapor prism as indicated by Wood (Wood's Optics, pp. 420-21). In this article a method is described that by means of a prism of sodium vapor, this dispersion may be conveniently shown and also photographed. The apparatus is easily made and material can be purchased for a few cents.

Material. A piece of iron bicycle tubing, approximately 2.5 cm. in diameter and about 30 cm. long may be used, together with a few feet of copper automobile gas line tubing. A tube is soldered in the top of the tubing near one end in order to evacuate the tube after it has been sealed. Within the tube are placed a few small pieces of metallic sodium. Over each end of the tube is sealed tightly a piece of double strength glass. Each end and the top of the tube is cooled by running water. The bottom of the tube is heated by a series of gas burners. The tube is evacuated to 4 or 5 cm.

Method of Cooling. Four turns of the copper tubing were made around each end of the iron tube. Two strips were placed from end to end across the top of the tube. The three pieces, on top and ends, were soldered at one end to a single intake tube approximately three times the size of the copper tubing. The other ends of the respective pieces of tubing were soldered to a single outlet tube. Having each piece of tubing coming from the same intake permits water to pass around each end and across the top at the same temperature. The intake is connected with a water faucet, the outlet to a drain. The round copper tube across the top is a double means of keeping the top cold, which is especially necessary to demonstrate the absorption band and dispersion. The cold copper tube is in direct contact with the iron tube which furnishes one source of cooling, but the chief source is probably in the fact that moisture is constantly being condensed from the air and gas which collects on the top of the iron tube. This is indicated by the moist appearance of the tubing and the frying noise as the water evaporates. The temperature gradient of the sodium prism thus formed seems to be apparently uniform, making possible the use of the whole aperture of the tube, permitting more light to pass through it.

The tube containing the sodium should be evacuated to about 4 or 5 cm. It is best that the tube should be sufficiently tight to hold this vacuum four or five hours so the pump or aspirator need not be kept running continuously. The burners should be arranged to control the heat for the proper temperature.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

This furnishes a neat, inexpensive method for showing the dispersion. With the apparatus once set up (fig. 1) the dispersion can be obtained in two or three minutes. Several demonstrations may be made over a period of several weeks with one filling of sodium. In the

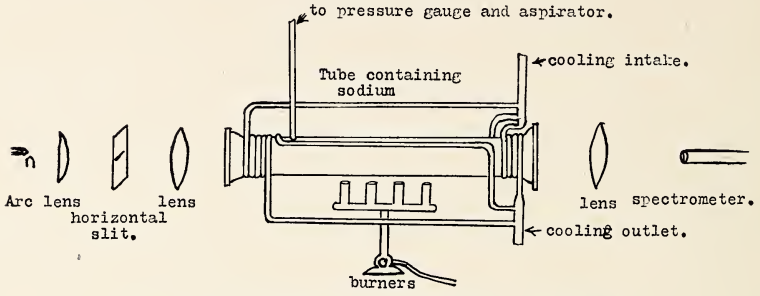

Fig. 1—Apparatus used to show anomalous dispersion.

spectrometer used the absorption band was a distinctly black band apparently 1 mm. wide. The image can be obtained and held sufficiently long enough to photograph. It is this extensive cooling, especially of the top while the bottom of the tube is being heated, that makes the density gradient uniform, thus forming the clear cut image.

SOME INTERNAL PARASITES OF POULTRY.

OTHO J. PRICE, Honey Creek High School, Terre Haute.

The modern poultryman is not guided by fancy's pictures of his flocks. One regularly carries two pictures of farm poultry. The chick is seen scratching in the soil of the poultry park, searching for earthworms, slugs, insect eggs, and other animal food. The hen is thought of as a fowl busily searching in the litter of the poultry house for stray particles of grain. Upon such a program, the flock to-day would result in failure. Increasing ages of domesticity have not only multiplied the internal parasites of the chicken but have as well forced the poultryman to practices of greater caution. Accordingly, the chicks are reared, in the most careful manner, in clean brooder houses, the windows of which are screened against flies and the floors of which are kept clean daily; the hens are fed all mash rations so that the possible filth of the floors may not contaminate their food.

Complete isolation from infestation is hardly possible. There are at least 20 parasites that attack the internal organs of chickens, and it is next to impossible, on a farm scale, to prevent absolutely all of these from invading the flock. Certainly it is necessary to keep away from the flocks, flies, earthworms, certain slugs, and such other carriers as sparrows, dust, and the shoes of careless visitors.

Two Parasites of the Chick. The chick is host to two minute animal parasites—the gape worm and coccidia. The first of these to become evident is the gape worm (*Syngamus trachealis*), the best known of internal poultry parasites because it is made evident by the gasping or gaping of chicks whose windpipes become partially blocked by the worms and the mucus that their attack produces. Gape worms are peculiarly interesting because of the habit of the mature males imbedding the posterior end of their bodies in the bodies of the female and maintaining the resulting Y appearance during the remainder of their lives. This position is made possible by the fact that the female is .5 inch long and the male but .2 in length. The female produces an average of 2,000 eggs[1], which pass out in the droppings or are sneezed out to pass through a period of incubation in the soil or in the bodies of earthworms, after which they are eaten to infest other birds.

Many chicks die from microscopic protozoan parasites called coccidia (*Eimeria avium*) which enter the body in filth and so irritate the ceca that they ooze blood. Birds so infested may survive, but are apt to constitute the unprofitable hens of the flock that transmit coccidiosis to the young of following years.

[1] Bunyea, Hubert, Dis. of Poultry, Rept. Bur. of An. Ind., 1927.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

Three Classes of Parasites of Adult Chickens. The intestines of adult chickens are hosts to a dozen forms of worms. It is our experience that no fowl is entirely free from some form, and that, where one form appears in large numbers, other species are also present. We find round worms, thread worms, and tape worms in fowls that are given the freedom of old yards. Round worms are commonest and thread worms the least common.

Of the round worms, perhaps the large intestinal worm (*Ascaridia galli*) is most plentiful. It is whitish to yellowish, the male about three inches and the female about four inches long. The numerous eggs that pass in the droppings go through a maturation period in or on the soil so that when taken up with food, the nascent nema are ready for the new host.

As an example of the smaller nematodes, the heterakid (*Heterakis gallinae*) or cecum worm appears abundantly. It is white and averages .4 inch in length. When present at all, it is found in great numbers. Its presence is sufficient to destroy the productiveness of a hen.

Old birds have been found with the great thread worm (*Gordianea avium*) in their intestines. Specimens approaching six inches in length give the impression of being insignificant because of their ability to contract and twist their bodies.

To the research student, the most interesting parasites are the tape worms. Their life cycles are elusive because of the necessity of an intermediate host. Eggs of an adult tape worm do not affect a chicken. It is known that the list of hosts[2] includes the stable fly, slugs, and the larvae of some insects. This situation is suggestive of the wide range of exposure to which the chicken is subject. The harm that results from attack is illustrated by the facts that the spiny suckered species (*Davainea echinobothdrida*) produces permanent disarrangement of the intestinal walls by nodular growths, while the sphenoid species (*Amebotaenia sphenoides*) produces emaciation. The first species approximates four inches in length, while the latter is hardly .2 of an inch long. Both are common in Indiana flocks.

From these observations, we are led to agree with Dr. S. B. Freeborn, of the California State Experiment Station, in considering the common chicken a walking menagerie, the host to a half million interesting, even if inconvenient and inconspicuous animal parasites.

[2] Hall, M. C., Farmers' Bull. U. S. D. A., No. 1337, 1927.

INSECTS OF INDIANA FOR 1928.

J. J. DAVIS[1], Purdue University.

The following account is a summary of the more important insect problems of the year. The first annual account published in the Proceedings was for 1925. These records should prove of future value in determining causes for insect abundance and in predicting insect troubles.

Weather Conditions. January, February and March were not far from normal. However, in February and March, cold periods and freezing and thawing when little or no snow covered the ground resulted in serious damage to wheat. April was cool throughout as was also May for the most part. This cool weather had a noticeable retarding effect on fruit blossoming and on insect development. June was unseasonably cool but with high rainfall. Insect development was somewhat retarded during this period. July was normal, especially so during the latter half, as was also August. September was cool and dry which retarded development of insects, such as the Hessian fly, which are normally active at that season. October, in contrast with the previous month, was abnormally warm. (Table I, fig. 1.)

CEREAL AND FORAGE INSECTS.

Grasshoppers (*Melanoplus differentialis* Thos.) continued scarce in most portions of the state. Sazama reports this species more abundant than 1927 and some injury to soybeans at Vincennes in late summer of 1928.

White grubs (*Lachnosterna* spp.) were reported abundant in soil at New Carlisle, La Grange, Washington, Crown Point and Lagro. Apparently all were in their third year of development. They were responsible for winter-killing of lawn grass at Elkhart and damaging strawberry plantings at Elkhart (May 27), Mulberry (June 5), and Summitville (July 1). Garden crops were injured at Mishawaka, June 18. Asilid larvae were reported very abundant in soil in St. Joseph County, June 23, where grubs were abundant last year. At Tipton grubs damaged Delphinium May 21.

Wireworms (*Elateridae*) damaged corn at Liberty (May 21), Covington (May 26), and Salem (June 20), and to potatoes Indianapolis (August 5).

Hessian fly (*Phytophaga destructor* Say) situation was reported by C. M. Packard, as follows: "Wheat went into the winter a year ago

[1] The writer is indebted to H. F. Dietz, B. A. Porter, R. F. Sazama, C. M. Packard, H. K. Riley, L. F. Steiner and Neale F. Howard for records.

Contribution from the Department of Entomology, Purdue University Agricultural Experiment Station.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

TABLE I. Comparative Monthly Weather Data for Indiana, 1928

Month		Temperature		Precipitation		Number of days		
		State mean	Departure from normal	State Average	Departure from normal	Clear	Partly cloudy	Cloudy
		°F	°F	ins.	ins.			
January	Normal	28.6	4.6	3.05	1.21	10	7	14
	1928	29.0	+0.4	1.74	−1.31	13	7	11
February	Normal	29.6	4.1	2.51	1.19	9	7	12
	1928	32.0	+2.4	2.79	+0.25	9	6	14
March	Normal	40.7	3.9	3.86	1.54	10	8	13
	1928	39.6	−1.1	1.81	−2.05	11	9	11
April	Normal	52.0	2.1	3.49	1.23	11	9	10
	1928	48.0	−4.0	2.95	−0.54	11	10	9
May	Normal	62.2	2.6	4.01	1.07	12	10	9
	1928	61.0	−1.2	2.95	−1.06	15	9	7
June	Normal	71.6	2.2	3.83	0.96	13	10	7
	1928	65.8	−5.8	7.05	+3.22	8	9	13
July	Normal	75.3	1.7	3.40	1.05	15	11	5
	1928	74.7	−0.6	3.55	+0.15	17	11	3
August	Normal	73.3	1.7	3.31	1.04	15	10	6
	1928	74.6	+1.3	3.80	+0.49	16	11	4
September	Normal	67.0	2.6	3.12	1.02	15	8	7
	1928	62.6	−4.4	1.26	−1.86	19	8	3
October	Normal	54.5	2.5	2.69	1.16	15	7	9
	1928	58.2	+3.7	3.55	+0.86	15	7	9
November	Normal	42.2	2.4	3.90	1.19	12	7	11
	1928	43.5	+1.3	3.16	−0.74	9	4	17

containing on the whole light infestations of Hessian fly. The widespread plowing up of winter-killed wheat last spring was an important factor in keeping down fly abundance. In northern and central Indiana spring fly development was retarded by lack of moisture and low temperatures. Weather conditions in southern Indiana, however, were more favorable to fly activity and considerable spring infestation developed there, some fields suffering material injury.

"There was little growth of volunteer wheat during the summer and no fly activity. These conditions continued until late September due to lack of sufficient rainfall and humidity to cause general pupation. Fly emergence this fall was, therefore, retarded considerably beyond the normal time throughout the state, and material infestations developed in seedings made on or within a week following the normal fly-free date. In mid-November the insect was still largely in the larval stage though some had formed puparia.

"Owing to the general scarcity of fly in northern and central Indiana last spring and fall weather conditions unfavorable to them no serious infestations have developed this fall in this part of the state. In southern Indiana, however, particularly the southwestern portion, the greater abundance of flies surviving the summer, the large acreage of early seeding, and the retarded though plentiful emergence of adults, have combined to produce severe infestations of Hessian fly in much of

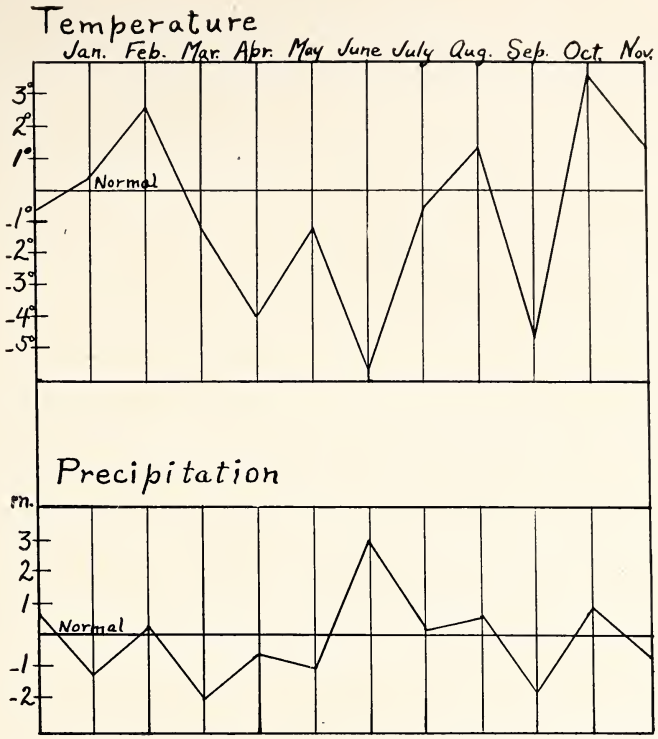

Fig. 1—Departures from normal temperatures and precipitation in Indiana for the year 1928, based on data in Climatological Data, issued monthly by the U. S. Weather Bureau.

the earlier seeding, with a prospect of serious losses to the current crop."

Chinch bug (*Blissus leucopterus* Say) was not observed in injurious numbers anywhere in the state.

Fall Armyworm (*Laphygma frugiperda* S. and A.) appeared in destructive numbers, according to reports received, in only one locality, namely Monticello (September 17), where three acres of alfalfa were destroyed.

The common armyworm (*Cirphis unipuncta* Harv.) was not once reported during the season. Late in May, Steiner reports numerous armyworm moths in codling moth bait traps, which was indicative of armyworms outbreaks.

European corn borer (*Pyrausta nubilalis* Hbn.) continued to extend its distribution in Indiana and to increase in abundance in the older infested areas. Scouting in 1926, the year of the first occurrence in Indiana, revealed its presence in 39 townships in six counties. In 1927, more intensive search showed its occurrence in 89 additional townships in a total of 16 counties. It was evident that some of the townships first found infested in 1927 were 1926 infestations, the facilities of the

federal scouting force being insufficient to find the extreme limits of infestation in 1926. In 1928, 56 additional townships were found infested, with a total of 21 counties. The slow spread in 1928 may be attributed to the short period of moth flight which did not permit as rapid spread or as distant flight as in previous years. The infestation in the older infested counties is increasing according to expectations. D. J. Caffrey, in charge of corn borer investigations for the U. S. Bureau of Entomology, has furnished us with the following statement based on extensive counts made in the six Indiana counties first infested in 1926.

Maximum percentage of plants infested in any one field (Otsego Township, Steuben County) .....3.2 per cent.
Maximum average borer population, per township (York Township, Steuben County) per 100 plants.....1.94 per cent.
Maximum average percentage of plants infested, per township, (Richland Township, Steuben County)..1.22 per cent.

The effectiveness of recommended clean-up practices were clearly demonstrated in Canada, Lucas County, Ohio, and elsewhere. Excellent progress has been made by federal and state workers in corn variety studies, mechanical methods of destroying crop residues, and introduction of parasites. G. A. Ficht, Purdue University Agricultural Experiment Station investigator, who is conducting fundamental research studies at the federal laboratory at Monroe, Michigan, reports excellent progress in studies on the behavior of the moth and other fundamental studies which will be of much value in developing future controls.

The common stalk borer (*Papaipema nitela* Gn.) was again conspicuously abundant and destructive. The first report was received May 17 from Indianapolis where second instar borers were injuring tomato plants in outdoor hot beds. The first report of injury to corn was from Stewartsville, May 30, followed by reports beginning June 17 and continuing into September, from Delphi, Hope, Franklin, Frankfort, Logansport, Hartford City, Lowell, Atlanta, Attica, North Liberty, Linden, Thorntown, New Richmond, DePauw, Greenfield, Rockville, Waynetown, Stendal, Monon, Remington, Plymouth, Owensville, Clinton, Tipton, Aurora, Petersburg, Albany, Peru, Jeffersonville, Fowler, Madison, Worthington, Heltonville, Williamsport, Cynthiana, Whitestown, North Vernon, Camden, Gaston, Greensburg, Brownstown, Lafayette, Indianapolis, and Kimmel. The large majority of reports referred to corn as the principal host. Early injury resulted in killing the central shoot but during August the injury included weakening the stalk causing the plants to break over in some cases. Other crops reported damaged included sweet corn, popcorn, wheat, oats, barley, tomato, potato, mint, dahlia, zinnia, hollyhock and strawflower.

Corn earworm (*Heliothis obsoleta* Fab.) was unusually scarce and not noticed at all until late in the season.

Billbugs (*Sphenophorus zeae* Walsh and *S. parvulus* Gyll.) were unusually abundant and destructive throughout central Indiana. *S. zeae* was decidedly the predominant species. The reason for this out-

break of billbugs can be traced back to the winter of 1926-27 when much of the clover was winter-killed. The wet spring of 1927 was responsible for a rank growth of grass and timothy, offering ideal conditions for maximum increase of billbugs. This ground heavily invested with billbugs, was planted to corn in the spring of 1928 and the resulting damage followed. The first reports of damage reached us May 18 and the beetles were active until June 4. Damage to corn (fig. 2) was reported from the following counties: Benton, Blackford, Boone, Carroll,

Fig. 2—Billbug injury to corn, showing at left typical early injury. At right, effect of early injury, causing tillering, stunting or death of corn plant.

Clinton, DeKalb, Fayette, Fountain, Grant, Howard, Johnson, Madison, Parke, Rush, Tippecanoe, Tipton, Union, Wayne, and Cass.

Webworms (*Crambus caliginocellus* Clem., et spp.) were abundant in the same areas infested by billbugs but the injury resulting was less serious. Evidently the conditions favoring billbug increase were responsible for the abundance of webworms. Definite reports were received from Bartholomew, Boone, Carroll, Fayette, Fountain, Grant, Henry, Jasper, Miami, Morgan, Stark, St. Joseph, and Union counties. The first reports were received May 17 and the last May 31. In all cases injury to corn was reported, excepting the report from St. Joseph County, May 31, where the worms were damaging mint.

The striped flea-beetle (*Systena taeniata* Say) destroyed three acres of soybeans at Clinton, July 7. A small black species (probably *Epitrix cucumeris* Harr.) was reported damaging corn at Connersville, May 24.

Tipulid larvae (Tipulidae) were abundant and reported cutting off corn at Anderson (May 26) and Delphi (June 2).

Cutworms (*Euxoa* sp.) destroyed three or four acres of corn at Winamac, June 2, and according to a report received July 1, the yellow-headed cutworm (*Hadena arctica* Bvd.) caused considerable damage to corn in the same locality. The greasy cutworm (*Agrotis ypsilon* Rott.) was abundant and apparently killing bent grass on golf greens at Bluffton, September 8.

Zebra caterpillar (*Ceramica picta* Harr.) was reported attacking field corn at Marion June 16 and Franklin June 25. This species also received from McCoysburg, June 16, on peas; from Rockville, June 23, on sweet corn; from Judson, June 27, on onion; and from Thorntown, July 2, on peas, cabbage and beets.

The saddle back caterpillar (*Sibine stimulea* Clem.) was sent in from every section of the state for identification but in only one case (Franklin, August 17) was information given. In that case it was reported as occurring on corn. All reports came in the last half of August.

An interesting case-bearing lepidopterous larva, determined by August Busck as a new species of *Coleophora*, was reported from Lapel, June 6, feeding on grass and timothy (fig. 3). The observer reported their presence on the grass appeared as oats scattered in the vegetation.

The pea aphid (*Macrosiphum pisi* Kalt.) was widespread and destructive to alfalfa in Elkhart and LaGrange counties May 21. This aphid was apparently also general in Fulton County about the same time, for ladybird beetle larvae were very abundant in an alfalfa field May 28 where the pea aphid had been destructive a short time before.

Clover leaf weevil (*Hypera punctata* Fab.) was damaging sweet clover at Marion, May 17, and common on alsike clover at Waveland May 28. Not generally destructive this year, however; in fact it was less common than usual.

VEGETABLE INSECTS.

Cabbage worm (*Pontia rapae* Linn.) damaged cabbage at Warsaw and Marion, July 23 and 24, respectively.

Cabbage curculio (*Ceutorhynchus rapae* Gyll.) damaged cabbage at Battle Ground, May 28.

Cabbage and radish maggot (*Hylemyia brassicae* Bouche) reported damaging radish at Logansport, May 29, and Morocco, May 26, and injuring cabbage at South Bend, May 31.

Striped flea-beetle (*Systena taeniata* Say) destroyed 13 acres of recently transplanted tomatoes at Worthington, June 16.

Black potato flea-beetle (*Epitrix cucumeris* Harr.) reported damaging potato at Ambia, July 6; also at Vincennes. Dietz reports this species as damaging potato and tomato in Marion County May 31.

Potato leaf-hopper (*Empoasca fabae* Harr.) injured potatoes at Nappanee, June 6, Waterloo, July 21, Bringhurst, July 25, and at Vincennes.

A stem borer, probably the potato stalk borer (*Trichobaris trinotata* Say) damaged potato at Deputy, June 22.

Fig. 3—A new species of case-bearer found on grass. The numerous cases attached to grass gave the appearance of scattered oats.

Fig. 4—The cause of spotting of onion foliage and dying of tips which was very prevalent in 1928 is unknown although there is some evidence that a common leaf-hopper is responsible.

Onion thrips (*Thrips tabaci* Lind.) not generally abundant. Only report of injury received was from Elwood, July 17.

Onion maggot (*Hylemyia antiqua* Meig.) apparently more destructive than for several years. Reports of damage were received as follows: Rensselaer, June 3, Plymouth, June 6, Elkhart, June 6, Warsaw, June 8, Angola, June 11, Bourbon, June 26, and Calumet City, July 17.

A common leaf-hopper (*Cicadula 6-notata* Fall.) (DeLong det.) was thought to be responsible for an onion trouble which was general in the northern half of Indiana during August, causing thousands of dollars damage. The injury is indicated by small white streaks on the foliage, superficially resembling thrips injury, shortly thereafter the tops wilting over and turning brown (fig. 4). Dr. M. W. Gardner, of the Purdue Botany Department, does not consider it a plant disease. The evidence against the leaf-hopper is largely circumstantial.

Striped cucumber beetle (*Diabrotica vittata* Fab.) was serious on cucumber at Forest, June 15. Earlier (May 31) it entered cucumber greenhouses at Indianapolis and caused much damage.

Fig. 5—The pickle worm was very abundant in 1928. At right, infested pickles showing exit holes. They become yellowed, eventually collapsing since the worms completely hollow out the fruit. At left, inside view of infested pickle.

Pickle worm (*Diaphania nitidalis* Stall) (fig. 5) was very abundant and destructive in several sections. Reports with specimens were received from Evansville, August 20, Decatur, August 25, Bluffton, August 28, and Boonville, September 18.

Mexican bean beetle (*Epilachna corrupta* Muls.) was reported from the following counties not hitherto recorded: Madison, Grant, Howard, Allen, Whitley and Steuben. No reports of further westward spread have been received. Evidence indicates that it may be occasionally destructive a little north of Indianapolis.

Bean root aphid (*Prociphilus erigeronensis* Thos.) reported damaging beans at Shelbyville, June 21, Pennville, July 5 and Salem, July 2.

Turnip aphid (*Aphis pseudobrassicae* Davis) was destructive to turnip this past fall at Indianapolis and Greensburg.

Greenhouse centipede (*Scutigerella immaculata* Newp.) was destructive in greenhouses in central Indiana. Experiments at Lafayette and Indianapolis by H. K. Riley have resulted in effective control of this pest of lettuce and other greenhouse vegetables, by carbon bisulphide fumigations.

FRUIT INSECTS.

Sowbugs (*Isopoda*) damaged mushrooms at Culver, June 6.

Codling moth (*Carpocapsa pomonella* L.) was normally abundant in southern Indiana although early season conditions were unfavorable and the numbers overwintering less than normal, due largely to a scarcity of fruit in 1927. The regular spray schedule gave good re-

sults. According to observations by B. A. Porter at Vincennes and L. F. Steiner at Bedford, the first moths did not emerge until May 14 at Vincennes and May 16, at Bedford, the delay being due to cool weather in April and early May, which likewise delayed apple blooming. At Bedford, the first eggs were observed May 17, but cool weather following did not permit hatching until May 26. At Vincennes, the first eggs hatched June 1, but not in numbers until June 10, the cool, wet weather since petal fall being responsible for the late hatching date. The generally unfavorable weather conditions during the appearance of the first brood held infestations to a minimum but favorable conditions during the last half of July and during August were responsible for an abundance of second and possibly third brood worms in many sections. Unlike 1927, there was a distinct period of about ten days between the first and second broods, due probably to a scarcity of hibernating worms. In 1927, the two broods overlapped about a week. In spite of this difference the second brood worms, however, appearing about the same time this year as last. Second brood worms began hatching July 23 in 1928 and the same date in 1927.

With an abundance of late worms and sufficient fruit to carry them through this past fall, large numbers are going into hibernation, which would lead us to predict an abundance of codling moth in 1929 if conditions this winter and next spring are normal.

Plum curculio (*Conotrachelus nenuphar* Hbst.) seems to be definitely on the increase in most orchard sections. Porter reports the curculio more abundant than usual on peach and apple in southwestern Indiana and his observations show considerable damage even in "pretty well sprayed" orchards. Other conditions equal, there is more curculio damage in dusted than in sprayed orchards.

Peach tree borer (*Aegeria exitiosa* Say) is still reported as a pest but Porter observes that the regular use of paradichlorobenzene in some sections, as in Knox County, has reduced the numbers almost to extermination.

Tarnished plant bug (*Lygus pratensis* Linn.) more abundant than last year according to Porter. Likewise there is more "cat-facing" of peaches than in 1927.

Green stink bug (*Nezara hilaris* Say) less common than usual on peach at Vincennes.

San Jose scale (*Aspidiotus perniciosus* Comst.) was very scarce this past year and there was less specking of fruit than for many years. In his check experimental block, Sazama found only two out of 600 alive. This was due to the high winter mortality. First crawlers were observed at Vincennes June 15, which was abnormally late.

Rosy apple aphis (*Anuraphis roseus* Baker) was abundant early but naturally checked in most orchards before serious damage resulted.

Shot hole borer (*Scolytus rugulosus* Ratz.) was not generally destructive. This beetle was apparently responsible for the death of apple and peach shoots by boring into the base of foliage and fruit spurs at Washington during June.

Oblique-banded leaf-roller (*Cacoecia rosaceana* Harr.) was observed eating into fruit of peach, June 22, but was not common.

Rose beetle (*Macrodactylus subspinosus* Fab.) was abundant in some sections. At Michigan City it damaged iris flowers and foliage and fruit of apple; at South Bend attacked roses; at Goshen damaged green peaches; at Winamac they were generally abundant; at Monterey young apple and plum trees; at Ray every apple in a ten-acre orchard was damaged; abundant at Crown Point, June 9-July 5, and at Medaryville causing death of young chickens, June 18.

Cotton caterpillar moth (*Alabama argillacea* Hbn.) was again completely absent.

Cherry slug (*Caliroa cerasi* Linn.) was moderately abundant in all sections of the state, occasional trees being defoliated.

Yellow-necked apple caterpillar (*Datana ministra* Drury) common on quince at Franklin, August 18, and on apple at Oden previous to October 2.

Oriental fruit worm (*Laspeyresia molesta* Busck) is definitely known to be well established in southern Indiana. Heavy losses occurred in Floyd and Dearborn counties. Other definite infestations are known from Vanderburgh, Posey, Warrick and Knox counties, in a few orchards rather severe. Steiner collected two worms in peaches at Mitchell which are almost certainly the oriental fruit worm, although adults were not reared. Peach was the host observed (fig. 6), excepting in one of our records from Dearborn County where the fruit (fig. 7) of a small quince orchard, normally yielding over 100 bushels, was completely ruined.

Fig. 6—Early season infestation by the Oriental fruit worm recognized by the dying peach twigs.

Late season leaf-hoppers (*Erythroneura obliqua* Say, *E. hartii* Gill. and *E. maculata* Gill.) were present in many sections causing a specking of apples by excrement dots (fig. 8). The first named species is probably largely responsible in Indiana.

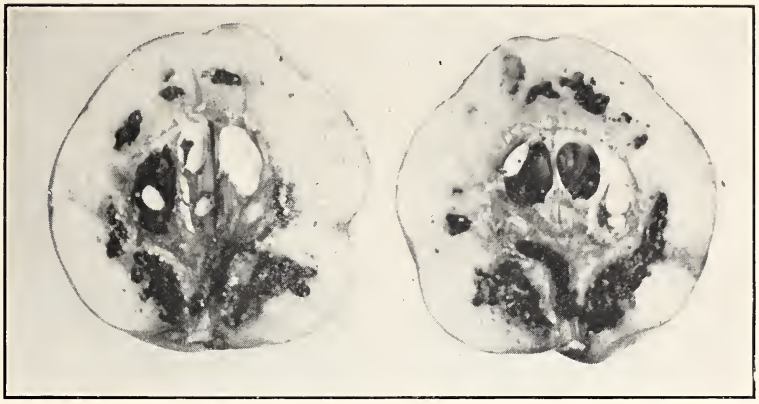

Fig. 7—Cross section of quince showing typical infestation by Oriental fruit worm.

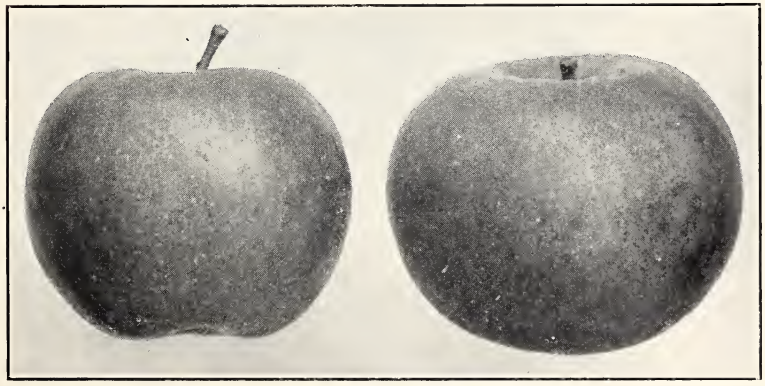

Fig. 8—Leaf-hoppers not only injure apple by sucking the juices from the foliage, but speck the fruit with excrement as in the illustration. (⅔ natural size.)

Potato leaf-hopper (*Empoasca fabae* Harr.) was about as abundant on apple as the year before, according to Porter.

European red mite (*Paratetranychus pilosus* C. and F.) was noticed in many orchards and seems to be generally distributed but no commercial damage reported.

Tree cricket (*Oecanthus nigricornis* Walk.) eggs were reported commonly in raspberry canes in central Indiana during April.

Raspberry fruit worm adults (*Byturus unicolor* Say) were damaging both red and black raspberries in LaPorte County, May 21. This is the

second consecutive year these beetles have been destructive according to our correspondent.

Raspberry sawfly (*Monophadnoides rubi* Harr.) (determined from foliage injury) was abundant at North Manchester, June 9.

Gooseberry gall aphis (*Aphis houghtonensis* Troop) reported damaging gooseberry at Greensburg, July 7.

The currant worm (*Pteronidea ribesi* Scop.) defoliated gooseberries at Lafayette. The larvae were full grown May 24. Dietz reports serious damage to both currants and gooseberries in the vicinity of Indianapolis, May 23.

Strawberry leaf-roller (*Ancylis comptana* Frohl.) was reported abundant in the egg and moth stages at Walkerton, May 2, where the leaf-roller was very destructive last year.

A strawberry slug (*Empria* sp.) damaged strawberry at South Bend, May 31.

Strawberry crown borer (*Tyloderma fragariae* Ril.) reported by Dietz as increasing in Floyd County, serious in Clark County and isolated infestations in Cass County.

SHADE TREE AND SHRUB INSECTS.

Cottony maple scale (*Pulvinaria vitis* Linn.) was again conspicuous and destructive throughout central and northern Indiana. Reports usually on soft maple, but occasionally on grape. Ladybird beetles (*Hyperaspis binotata* Say) were conspicuously abundant in central Indiana where the cottony maple scale has been destructive. In spite of their numbers they do not appear able to effectively check the scale.

Elm scurfy scale (*Chionaspis americana* Johns.) was normally abundant and continues as an important pest of young elms. Spray tests made by Riley at Lafayette, April 16, 1928, just as the buds were ready to open gave complete control with three per cent Dendrol, Sunoco, and lubricating oil emulsion, and with a six per cent Volck. Volck was not tested at a lesser strength. This year eggs began hatching the first week in June at Lafayette.

European elm scale (*Gossyparia ulmi* Linn.) was abundant on elm at Marion, June 23.

Oyster shell scale (*Lepidosaphes ulmi* Linn.) was normally abundant. Killing of lilac and ash was reported from several localities. At Lafayette the eggs were first hatching, June 2. Dietz reports the light brown form from weeping birch.

The tulip tree scale (*Toumeyella liriodendri* Gmel.) abundant on tulip tree at Logansport, Salem, and Nashville.

Elm cockscomb gall (*Colopha ulmicola* Fitch) reported abundant at Frankfort, June 13. This gall insect is abundant throughout the state every year.

The giant aphid (*Longistigma longistigma* Monl.) was abundant at Brownstown, June 8.

Spiraea aphid (*Aphis spiraecola* Patch) was generally abundant on bridal wreath throughout the state as usual, during June and July.

Catalpa sphinx caterpillar (*Ceratomia catalpae* Boisd.) defoliated catalpa at Lafayette, Kingman, and Thorntown early in September. Not common at Vincennes according to Porter.

Red-humped oak worm (*Symmerista albifrons* S. and A.) defoliated 50 acres of oak near Crown Point, according to a report received September 18.

Tussock moth caterpillar (*Hemerocampa leucostigma* S. and A.) was not generally destructive although reported abundant and causing partial defoliation at Franklin, July 9, and Garrett, August 31.

Bagworm (*Thyridopteryx ephemeraeformis* Haw.) were common in southern Indiana. Reports of injury were received between June 15 and August 30, from Aurora, Columbus, Danville, Franklin, Indianapolis, Martinsville, Terre Haute, and Vincennes. At Vincennes some young apple orchards, not thoroughly sprayed, were damaged.

Fig. 9—The hickory horned devil, the immature stage of the beautiful regal moth, is very often sent to us for identification, not because it is a serious pest but rather because of its large size and conspicuousness.

Hickory horned devil (*Citheronia regalis* Fab.) (fig. 9) was frequently sent in the last part of August. No injury recorded and apparently all specimens were sent in for identification because of their conspicuousness.

Spruce budworm (*Harmaloga fumiferana* Clem.) damaged blue spruce and to a lesser extent Norway pine at Cambridge City, May 31.

Walnut caterpillar (*Datana integerrima* G. and R.) was not noticeable anywhere in the state according to observations and reports.

Locust borer (*Cyllene robiniae* Forst.) was reported destructive at Francesville, Vincennes, and Lafayette.

Red spider (*Tetranychus telarius* Linn.) abundant on evergreens at Rising Sun and Aurora during July and on juniper at Elkhart early in August.

Paratetranychus sp. near *unnunguis* (Ewing det.) was reported by Dietz as causing injury to Norway spruce in June in central Indiana.

The willow shoot sawfly (*Janus integer* Nort.) damaged basket willow at Richmond, July 19.

Catalpa leaf-miner (*Agromyza citreifrons* Mass.) was common on catalpa at Vincennes and Terre Haute early in August.

FLOWER GARDEN AND ORNAMENTAL GREENHOUSE INSECTS.

Iris borer (*Macronoctua onusta* Grt.) reported injuring iris at Greencastle, June 25, and Dietz reports it as abundant as last year in the vicinity of Indianapolis. Dietz observed first hatching of eggs at Indianapolis, April 30, and hatching continued until May 25.

Glassy cutworm (*Hadena devastatrix* Brace) damaged Delphinium at Tipton, May 21. The same correspondent reported injury to Delphinium by white grubs (*Lachnosterna* spp.).

Neodiprion pinetum Nort. (larval det.) was reported by Dietz as occurring and sometimes defoliating nursery and ornamental plantings of white pine and to a lesser extent Scotch pine in Elkhart, Hendricks, Howard, Kosciusko, LaPorte and Marion counties.

Rose slugs (*Caliroa aethiops* Fab.) were reported abundant at Connersville, Spiceland, Lafayette, Indianapolis, South Bend, Vincennes and Valparaiso, reports being received from the last of May through the month of July.

Blister beetles not as common as last year. This was to be expected with the continued absence of grasshoppers. The striped blister beetle (*Epicauta vittata* Fab.) damaged dahlia flowers at Connersville, July 18, and the black blister beetle (*E. pennsylvanica* De G.) was reported damaging flowers at Gary, Sept. 2, although less abundant than for several years.

Rose midge (*Dasyneura rhodophaga* Coq.) infestations were observed by Dietz the latter part of the summer in Henry, Howard, and Jay counties, but none were serious.

Chrysanthemum midge (*Diarthronomyia hypogaea* Lowe) was serious in Elkhart and St. Joseph counties, according to Dietz.

Bulb fly (probably *Eumerus strigatus* Fall.) reported by Dietz attacking garden iris at Indianapolis.

Columbine Leaf-miner (*Phytomyza aquilegiae* Hardy) was destructive to commercial plantings of aquilegia at Whiting, June 19. Frequent reports of injury to home plantings were received from all sections of the state.

Common meadow grasshopper (*Orchelinum vulgare* Harr.) was reported by Porter causing serious damage to rose in greenhouse at Vincennes, early in October, by ovipositing in the rose shoots.

The pea aphis (*Macrosiphum pisi* Kalt.) was damaging sweet peas at Woodburn, July 25.

Bean root aphid (*Prociphilus erigeronensis* Thos.) responsible for considerable damage to asters at Muncie in September and early October.

Phenacoccus gossypii Towns. and Ckll. (Morrison det.) was reported late in November, 1927, at Vincennes on chrysanthemum, the first record

as a greenhouse pest. In 1928 it was found at Vincennes, Terre Haute and Indianapolis.

The cyclamen mite (*Tarsonemus pallidus* Banks) was very destructive to Delphinium at Lebanon, May 21. The same mite was reported as similarly destructive in 1927. According to Dietz old infestations were cleaned up by spraying at ten-day intervals until nearly ready to bloom, using nicotine sulphate one to 500 plus soap. Dietz reports finding it for the first time on Shasta and field daisies and on petunia among delphinium. One report of 50 per cent loss to geranium in a large commercial planting.

Red spider (*Tetranychus telarius* Linn.) damaged phlox at Hanover, June 22.

Bulb mite (*Rhizoglyphus hyacinthi* Boisd.) reported by Dietz on peony.

Pests of Stored Products.

Bean weevil (*Mylabris obtectus* Say) damaged seed beans at Marion, June 22.

Angoumois grain moth (*Sitotroga cerealella* Oliv.) damaged wheat at Dyer, Aug. 5.

Indian meal moth (*Plodia interpunctella* Hbn.) damaged shelled corn at Albion, May 26.

Larder beetles (*Dermestes lardarius* Linn.) reported infesting home-cured ham at Auburn, August 18.

Household and Miscellaneous Pests.

Clothes moths (*Tinea pellionella* Linn.), common carpet beetles or "buffalo bugs" (*Anthrenus scrophulariae* Linn.) and black carpet beetles (*Attagenus piceus* Oliv.) were reported commonly throughout the year as usual. An interesting report from LaPorte called attention to damage to Rayon silk.

Booklice (*Troctes divinatoria* Mull.) were reported abundant in dwellings at Indianapolis and Lafayette, during August.

Silverfish (*Lepisma saccharina* Linn.) have been annoying and damaging book bindings at Lowell and Lafayette, during the past season.

Clover mite (*Bryobia praetiosa* Koch) was abundant and annoying in homes at Edinburg, Rushville, Converse and Lafayette during the last of April and first half of May. This mite was reported injuring lawns at Frankfort, May 12.

Cockroaches (*Blattidae*) were normally abundant in all sections of the state.

Fleas (*Ctenocephalus canis* Curt) was normally abundant, many reports being received from all parts of the state where they were reported troublesome in homes, barns and lawns. Reports were received frequently from April until September.

Ants (*Formicidae*) were generally destructive in lawns and in homes throughout the state. They were reported actually destroying strawberry and other plants in several cases. Dietz reports the large black carpenter ant (*Camponotus herculeanus* Linn.) as abundant in a number of residences in Indianapolis.

Mosquitoes (*Culicidae*) were very abundant at Lafayette and Muncie early in July.

An Ichneumon fly was sent in from Red Key, May 26, which was said to have stung a baby causing much suffering.

Ox warbles (*Hypoderma* sp.) were destructive at Winamac, Lafayette, and Frankfort, during April.

Cattle flies (hornfly, *Haematobia irritans* Linn., stablefly, *Stomoxys calcitrans* Linn., and house fly, *Musia domestica* Linn.) were reported from central and northern Indiana as causing considerable annoyance to dairy cattle during the last half of July.

Termites (*Reticulitermes flavipes* Koll. and *R. virginicus* Banks) were destructive to buildings throughout the state. In July they were damaging dahlia by tunneling the stalks.

Cerambycid larva (*Eburia quadrigeminata* Say, Craighead det.) was reported boring in a hickory-elm floor which has been down 35 years. This report came from Columbia City, May 5.

Powder post beetle (*Lyctus sp.*) damaged building timbers at Crown Point and Edinburg and shovel handles at Terre Haute.

THE WATER MITES OF LAKE WAWASEE.

RUTH MARSHALL, Rockford, Illinois.

The present paper is a study of the Hydracarina taken by Dr. Will Scott, of Indiana University, during the months of July and August, 1926 and 1927, from Lake Wawasee (Turkey Lake), in northern Indiana. Collections were made at several stations at moderate depths near shore in the course of ecological studies on the life of the lake. The author wishes to express her thanks to Doctor Scott for the opportunity to examine and report upon this material.

Over 250 individuals comprise the collection, most of which were identified. They are distributed among 15 genera and 27 species, four of which are new. In addition to these, the heretofore unknown males of two other species are described. Following the description is given a list of the species found.

Limnesia wawaseea nov. spec. (Figs. 9-11).

Two large males, found in Johnson's Bay, represent this unusual and rare species. The larger of the two individuals is 2.73 mm. long and nearly as broad and moderately elevated. The antennary bristles are short. The plates of the ventral side are heavy and show a reddish tinge in preservation. The first pair of epimera do not meet in the middle line and all of the groups are well separated; the inner margin of the posterior pair diverge at a wide angle. The genital area lies within the bay thus formed, slightly above the center of the body. The genital plates bear each four conspicuous rounded acetabula; about them numerous small circles are seen, the bases of very fine hairs. The presence of extra acetabula is unusual although not unknown. An African species, *L. asper* Koen., and its variety, *L. macrospora* Viets, show the same peculiarity, while an extra acetabulum on one plate is occasionally found in other species.

The capitulum is broad. The palpi are about one-third of the length of the body; the second segment is broader than the first leg and its peg on the flexor surface is very small and on but a slight elevation. Both the second and third palpal segments bear several short bristles which are slightly feathered. The fourth segment is very long and bears on the inner side near the distal end five fine hairs on slight papillae. The legs are slender, the fourth somewhat shorter than the body and well provided with swimming hairs and bristles.

Lebertia quinquemaculosa nov. spec. (Figs. 5-8).

A very large species, individuals attaining a length of 2 mm., broad oval in form. Fine, broken, irregular lines can be made out on the

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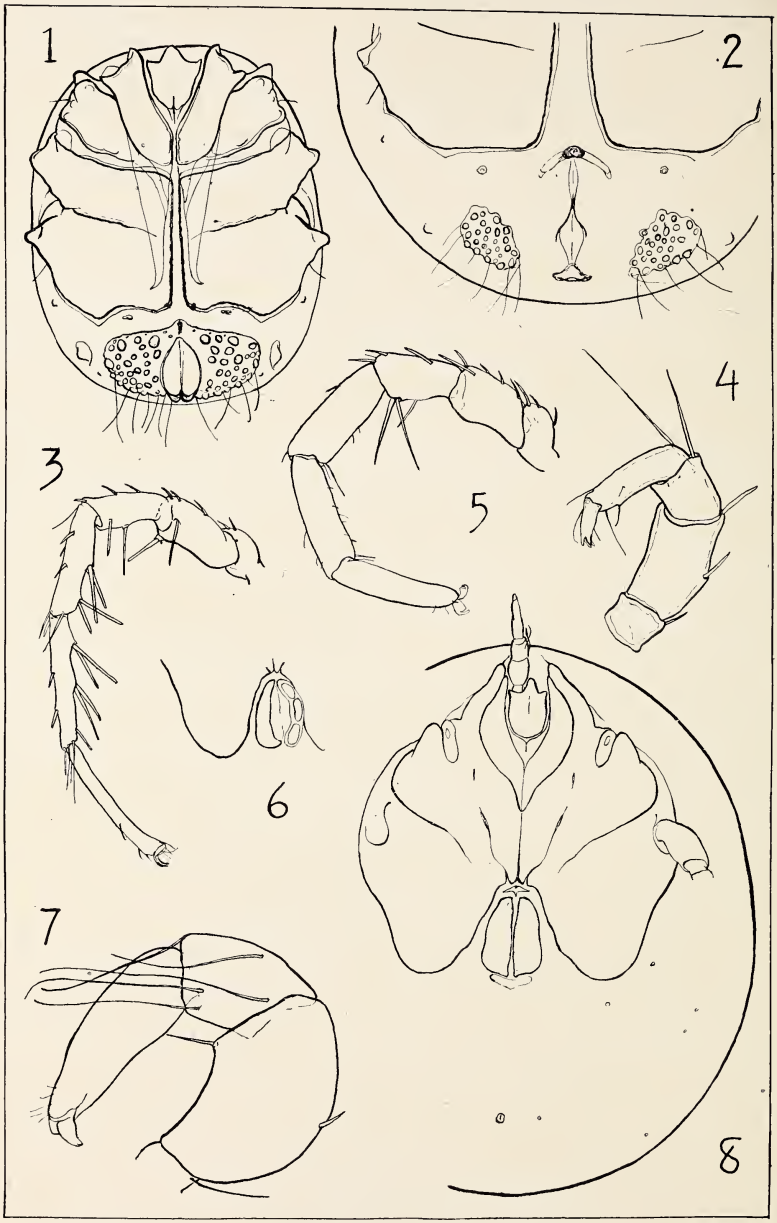


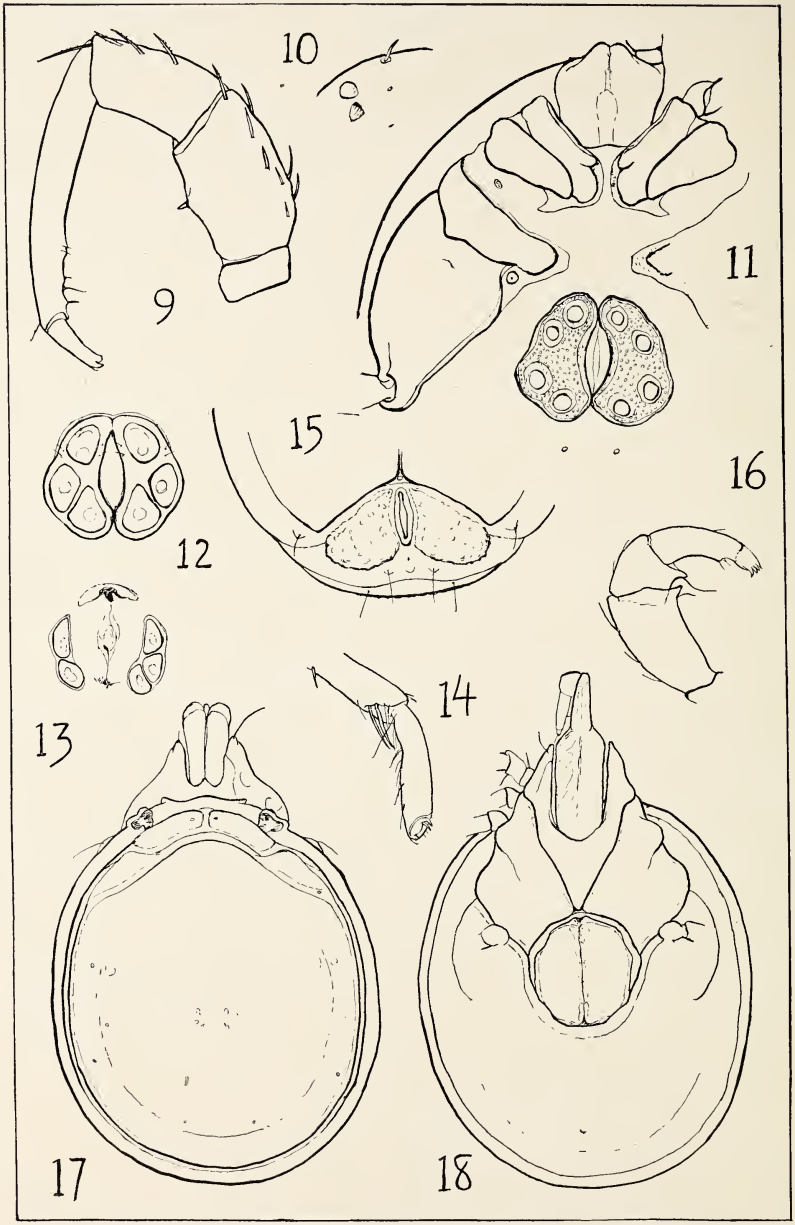
Figs. 1-8.—1, *Neumania pubescens*, male, ventral view; 2, female, genital area; 3, first leg; 4, palpus; 5, *Lebertia quinquemaculosa*, left first leg; 6, genital area, left plate turned back; 7, right palpus, inner side; 8, ventral view.

body, with small circles on the epimera and legs. The ventral shield of united epimera is relatively small. The first epimera are very narrow and short; the fourth are narrow at the posterior end and enclose a deep and broad bay, in which lies the genital area near the center of the body. The genital plates are elongated, broadened posteriorly; each covers three elongated acetabula of about the same size, which show faintly. The capitulum and palpi are small. The second segment of the palpus is stout and bears a small bristle on the inner concave side; the third is small with a few very long, slender hairs on the inner surface, and the fourth segment has a prolongation beyond the attachment of the fifth. The legs are short and stout and bear many heavy bristles; the second and third have each a tuft of hairs on the distal end of the fifth segment, while the fourth has large tufts on the fourth and fifth.

Four individuals were found in the Wawasee material; others have been found by the author in collections from Wisconsin from which notes on the living animals were made. The colors are striking: five bright red spots show dorsally (one anterior, one posterior, two lateral and one above the center), with a large ventral spot below the plates and sometimes several blotches besides. Occasionally, especially in young specimens, the red is diffused throughout the body. These spots are surrounded by brown blotches on a yellow green bright background. The plates are reddish blue or magenta, as are also the legs. The eyes are red.

Atractides indistinctus nov. spec. (Figs. 16-18).

Body oval, 0.70 mm. long by 0.60 mm. broad. The color is reddish brown in preservation. The body is strongly flattened dorso-ventrally and the integument is strongly chitinized and distinctly porous. Anterior to the large dorsal plate are two small oblong plates indistinctly outlined, while back of these and toward the margins of the body are indications of the two other plates commonly found here in species of this genus. In this respect the new species resembles *A. damkohleri* (Viets), an African species. The epimera are closely united to each other and to the general surface. The completely fused first pair are very long and the posterior end touches the genital area. The point of union of the second and third of each side is indicated by a line from the outer margin half way in. The outlines of the fourth pair are nearly obliterated on the posterior margins. The genital area is slightly broader in the anterior part and shows a heavy margin; at the meeting of the genital plates the outlines of oblong acetabula can be seen faintly. The capitulum is very long and with the points of the first pair of epimera extends considerably beyond the body margin. The palpi are relatively long and large. The second segment is long and bears a projection on the inner distal part, near which is a long hair; the third segment shows the same features. The terminal segment ends in four small finger-like processes. The legs are short and bear heavy bristles but no swimming hairs. The fourth leg, the longest, is but slightly longer than the body; the distal end of the last segment is conspicuously broadened.



Figs. 9-18.—9, *Limnesia wawaseea*, palpus; 10, double eye and antennary bristle, left side; 11, ventral plates, male; 12, *Megapus parviscutus*, genital area, male; 13, genital area, female, showing five acetabula; 14, distal end of first leg; 15, *Albia caerulea*, posterior ventral area, male; 16, *Atractides indistinctus*, palpus; 17, dorsal view; 18, ventral view.

One individual was found in the Wawasee collections; the species has also been found in Wisconsin. The specific name has reference to the character of the small dorsal plates which in related species are usually four in number and more clearly outlined. The long capitulum places the new species in the group of the "long-snouted" forms of the genus.

Neumania pubescens nov. spec. (Figs. 1-4).

Body elliptical, moderately arched, slightly depressed at the anterior end. Of the nine individuals found, one was a young male, 0.675 mm. in length, while the females ranged from 0.80 mm. to 1.03 mm. The body is semi-transparent and covered with very fine short projections. All plates and the appendages appear deep blue in preservation. The eyes are large, the antennary bristles long and fine. The epimera are large and heavy; they cover a considerable part of the ventral surface in the male but are relatively smaller in the adult females, with wider spaces between the groups. The underlying braces of the first pair are conspicuous and extend far back under the fourth. The dividing line between the third and fourth epimeral pair is not quite complete. The surfaces of the epimera show slight irregularities and the fourth has faint blotches. The genital areas in both sexes are situated well back, the slits long and not far from the last epimera. The united plates of the male form a broad oval; in the female the plates are widely separated, irregularly obovate in form. The acetabula in both sexes are conspicuous, irregular in shape, distribution and number. The plates are bordered by a row of long fine hairs, a feature which suggested the specific name. The palpi are relatively large, with heavy bristles, two of which on the distal end of the third segment are very long. The legs are stout and bear many stout bristles. The papillae supporting the bristles of the first leg are not conspicuously large. A few long, coarse swimming hairs are found on the last two pairs of legs, while some of the bristles of the older individuals are feathered.

Megapus parviscutus (Mar.) (Fig. 12-14).

Four females were found in three stations at depths varying from one-half to one and one-half meters. One individual had but two acetabula on the genital plate of the right side (fig. 13). The species has been found in several Wisconsin collections and the male is now known. This measures 0.70 mm. in length. The genital area is of the typical form (fig. 12). In living material the body is delicate and transparent, pale brownish red in color, with plates and legs bluish. A drawing is added of the end of the first leg (fig. 14), showing the slightly curved sixth segment and the two saber-like bristles on the proximal end of the fifth.

Albia caerulea Mar. (Fig. 15).

One individual of the collection was recognized as the undescribed male of this species. The characteristic colors were well preserved. The body is the same length as in the female (0.70 mm.) but is slightly

slimmer. The posterior border of the last epimeral pair is more distinct and angular in this sex, and the body here shows a slight protuberance and bears several hairs on papillae. The genital opening is well marked and has a thickened border. The genital areas are wing-shaped, faintly outlined on the anterior border, heavy on the posterior. The acetabula are numerous but faintly outlined. The entire genital area is broadly triangular and partly enclosed by a bay formed by the fourth epimera.

List of the Species.

Limnochares aquaticus (L.), *Limnesia undulata* (Müll.), *L. wawaseea* nov. spec., *Lebertia porosa* Thor., *L. quinquemaculosa* nov. spec., *Frontipoda americana* Mar., *Atractides indistinctus* nov. spec., *Hygrobates longipalpis* (Herm.), *Megapus parviscutus* (Mar.), *Unionicola crassipes* (Müll.), *Neumania pubescens* nov. spec., *Koenikea concava* Wol., *Piona spinulosa* (Wol.), *P. rotunda* (Kram.), *P. triangularis* (Wol.), *P. reighardi* (Wol.), *Albia caerulea* Mar., *Mideopsis orbicularis* (Müll.), *Krendowskiji ovata* Wol., *Arrhenurus infundibularis* Mar., *A. scutulatus* Mar., *A. manubriator* Mar., *A. megalurus* Mar., *A. parallelatus* Mar., *A. pseudocylindratus* Piers., *A. americanus* Mar., *A. falcicornis* Mar.

THE CHUCK-WILLS-WIDOW IN INDIANA.

AMOS W. BUTLER.

Last spring, in company with Mr. S. E. Perkins III, I visited the collection at Shortridge High School, Indianapolis, Indiana. Miss Rousseau McClellan, the teacher in charge, very kindly showed us the specimens. Our attention was drawn to some bird skins that were in pieces through much handling by pupils. Among those appeared the head of a Chuck-Wills-Widow (*Antrostomus carolinensis* Gmel.). Miss McClellan said it had been taken in Indianapolis and was brought to her by one of her pupils in April or May, 1908. It was found dead opposite public school No. 10 at the old Medical School Building. Evidently it had flown against the brick wall of that building. It was perfectly fresh when brought to her. She made a skin of it and put it in their collection of birds. She says Harry Dietz remembers it.

This is the first record of this bird from Indiana verified by a specimen and the farthest northern point in the state it has been reported. April 20, 1878, Robert Ridgway and William Brewster identified this species on the Indiana side of the Wabash River in Knox County but did not take a specimen. Dr. Ridgway says: "I have both seen the Chuck-Wills-Widow and frequently heard its unmistakable note in Knox County, Ind., immediately opposite Mt. Carmel" (Ill.) I am informed by Roy Chansler that he has at different times in recent years heard the distinctive note of this bird in Knox County.

[1] Butler, Birds of Ind. 1897, p. 846, 1847.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

COMPARATIVE RESULTS OF BIRD BANDING IN A LARGE CITY AND A SMALL TOWN.

FREDERICK CLEVELAND TEST, Northwestern University
and
LOUIS AGASSIZ TEST, Purdue University.

It would hardly be expected that bird banding in a large city like Chicago would be productive of extensive results when compared with similar results obtained in a small town like West Lafayette. Our results have been contrary to expectations and present some very interesting comparisons.

The results here discussed cover a period of exactly four years, from Dec. 1, 1924 to Nov. 30, 1928. The Chicago station is at 4620 Greenwood Avenue, in the heart of a residential district and half a block from a business street. The West Lafayette station is on the outskirts of the town at 511 Russell Street and nearly a mile from any business district with the Purdue Campus between. All captures included have been made in our back yards except for a few, mostly young birds, taken within the block. The two back yards are of approximately the same area, about 5,000 sq. ft., and each has some shrubbery and a few trees. The Chicago yard has the most shrubbery but the trees are all small, while in the West Lafayette yard there are five large trees. One of these is a wild cherry while the Chicago yard has a mulberry. Each yard has a bird bath and the amount and kind of natural food likely to attract birds is approximately the same. The number and types of traps used are similar as is also the bait used.

The chief differences lie in the surrounding environments. The Chicago station is in a thickly settled district with no vacant lots in the block and few, if any, shade trees on the street. It is half a mile from the lake, a mile from Washington Park and two miles from Jackson Park. Before this section was built up there was a spring within 100 yards of the station and a small stream flowed away from this spring which may have had some influence on this as a route of migration.

At West Lafayette there is a vacant lot on each side of the station and many shade trees along the street in front. At the back of the lot, to the west, is open country stretching away to a woods nearly a mile distant, while a quarter of a mile to the northwest is a small wood lot. The field immediately west is under cultivation; alfalfa, corn and oats having been the crops during the past four years. The neighbors' pet cats are rather numerous about both stations.

The banding in Chicago is confined almost entirely to April, May and early June and September, October and early November, while at West Lafayette some birds are banded every month in the year though

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

the number is small in February and November. Appended is a list of all birds banded at the two stations with a summary of the results. The captures are listed for spring and fall of each year, spring being considered from January 1 to June 30 and fall from July 1 to December 31. Under repeats and returns are listed the individuals for which repeats and returns are recorded and not the total numbers of captures. Under totals for West Lafayette the numbers marked (*) include birds banded in December, 1924, which are not included elsewhere in the table. No birds were banded in Chicago during this period.

It is interesting to note that while the total list contains 52 species there were exactly 38 species banded at each station. While the total number of species is exactly the same, more individuals were banded at West Lafayette than at Chicago, the former number being 975 and the latter 758. The West Lafayette figures do not include about 100 chimney swifts caught on the Purdue Campus and some other species, mostly young birds, banded elsewhere in the neighborhood. In all there are 16 families represented, 14 in the West Lafayette list and 12 in the Chicago list. In both lists, as might be expected, Fringilledae leads with 13 species for West Lafayette and 12 for Chicago. At Chicago Mniotiltidae comes second with 7 species but only one at West Lafayette. Turdidae is next with six species at Chicago and five at West Lafayette. Icteridae is represented by four species at West Lafayette and only one at Chicago.

In both lists the total spring captures considerably exceed those for fall, though in 1927 the fall captures exceed the spring in Chicago. In only four species do the total taken in the fall exceed those taken in the spring at each station. At West Lafayette the bluejays are exactly the same for both seasons, and robins are in excess in the fall in 1928.

Examining the totals further it is seen that at Chicago two species only exceeded 50 individuals, one being white-throated sparrows the highest on the list, while the West Lafayette list has four species of more than 50 individuals, the lowest of which has 80.

The great difference in the numbers of certain species banded at the two stations is remarkable. For example, bronzed grackles which lead in the number of captures for West Lafayette at 302 are entirely absent from the Chicago list though the bird is quite common in the parks and is frequently seen near the station. Doves and tree sparrows are two other prominent birds on the list which are entirely wanting in Chicago. On the other hand, fox sparrow with 51 bandings stands second on the Chicago list and is entirely absent from the West Lafayette list though they are fairly common in the region during migrations and there seems no reason why they should not come to the station. Towhee is also absent from this list though common in the region. More remarkable is the large number of white-throated sparrows banded in Chicago, 403, as compared with the 31 banded at West Lafayette. Why these birds should be caught in such abundance at one station and not at the other seems strange for they are always abundant in the vicinity of West Lafayette during migrations. This species is one of the few

showing a noticeably larger number banded in the fall than in the spring at both stations. Decidedly more than half of the Chicago captures are white-throated sparrows. The woodland species seems to predominate at Chicago and those of the open country at West Lafayette.

One of the most outstanding differences is the comparatively large number of repeats at Chicago and the large number of returns at West Lafayette. Over 22 per cent of the Chicago banded indivlduals repeated one or more times 99 of the 403 white-throated sparrows repeating, one as many as 77 times, being caught every day from Sept. 22 to Oct. 22, 1928. At West Lafayette the individuals repeating are less than 12 per cent of the total captures, and the highest number of repeats for an individual is 11 for a bronzed grackle.

On the other hand, the returns at West Lafayette are 84 or 8.6 per cent of all individuals banded, a number returning more than one year, while Chicago shows less than .5 per cent with only four individuals. Two of the latter were robins, one being found dead in Chicago and the other at Galveston, Texas. At the Chicago station returns are recorded for only three species, as follows: bluejay, brown thrasher and robins, while at West Lafayette there are returns for 15 species out of the 38 banded.

In summarizing, while the number of species banded is the same at each station the individuals are about one-fourth greater at West Lafayette where the residents number nine against three for Chicago. The transient birds which do not nest, number 16 at Chicago and 10 at West Lafayette.

Chicago shows a larger number of species for which only one capture each is recorded.

SUMMARY OF RESULTS

CHICAGO																WEST LAFAYETTE													
1925		1926		1927		1928		Total for each species	Re-peats	Re-turns	Bird	1925		1926		1927		1928		Total for each species	Re-peats	Re-turns
Sp	Fl	Sp	Fl	Sp	Fl	Sp	Fl					Sp	Fl	Sp	Fl	Sp	Fl	Sp	Fl			
							1	1			Saw-whet Owl											
											Screech Owl								1	1		
1								1			Downy Woodpecker	1	3	2		6	2	1		*16	7	5
1								1			Yellow-bellied Woodpecker											
2								2			Red-headed Woodpecker	2		4		1	3	3		13		
											Red-bellied Woodpecker	1			1		1			3	2	1
1					3			4			Flicker	2								*3		2
1	1							2		1	Blue Jay	7	6	6	4	2	17	25	11	*80	9	9
	1							1			Cowbird	1			4	1				6		
											Meadow Lark	1								1		
											Baltimore Oriole	1		5		3		2		11	6	3
											Bronzed Grackle	77	1	19	25	69	46	53	12	302	7	23
		1	1					2			Savannah Sparrow	1								1		
						1		1			Henslow's Sparrow											
4		5		3		2	1	15	5		White-crowned Sparrow	8		14				3		25	4	
12	21	42	12	41	99	82	94	403	99		White-throated Sparrow		2			2	4	10	13	31		
											Tree Sparrow	13		3		2		4		22	2	
1								1			Chipping Sparrow	3				3				6	2	
		2		1				3			Field Sparrow			1				1		2		
	2	19		10		15	1	47	9		Slate-colored Junco	13	4	38	21	35	8	60	6	190	25	8
											Montana Junco								1	1		
1		10		2	1	7	1	22	6		Song Sparrow	5	1	3		1	2	7		19	5	1
		3		2		1		6	1		Lincoln's Sparrow	1		3		1		2		7	1	
		11	1	3		4		19	2		Swamp Sparrow							1		1		
	10	2	9		2	20	8	51	16		Fox Sparrow											
2				6				8	1		Towhee											
											Cardinal	2		2		1		5	2	*13	1	4
											Indigo Bunting					1				1		
		1					1	2			Purple Martin											
1		1	1		2			5			Black and White Warbler											
				1		1		2			Nashville Warbler											
		2		4	1	11		18	1		Ovenbird								1	1		
		3						3			Water Thrush											
						1		1			Connecticut Warbler											
		1						1			Mourning Warbler											

			1		1		2			Western Yellow-Throat													
2		1		9		7		19	3		Catbird	1		5		7		8		21		1	4
5	4		1	14	4	2	30	15	1		Brown Thrasher	5	1	6	1	2	4	6		25		9	5
											Bewick's Wren							1		1			
	1	1	1		2	3	8	1			House Wren	4		1		2		2	13	22		6	1
3	3	5		2		4	17				Brown Creeper	1				1	1	2	3	8		1	
											White-Breasted Nuthatch	2	3	1			3	1		10		5	
											Tufted Titmouse	2		2	1	1				6		5	2
				1			1				Golden-crowned Kinglet												
					1		1				Wood Thrush												
					2	1	3				Wilson's Thrush	1				1				2			
1			1	1	2		5				Grey-cheeked Thrush	1			1	1		2		5			
	2		3		1		6	1			Olive-backed Thrush					3	1	1		5		1	
2		2	2	6	4	1	19	2			Hermit Thrush			1	1					2			
8	4	3	1	3	5	1	25	14	2		Robin	20		18		16	2	15	18	89		14	15
48	47	112	31	92	135	154	118	757	168	4	Total Species	185	21	135	59	174	94	213	84	975		115	84
95		143		227		272					52	206		194		268		297					

Chicago 38 species

West Lafayette 38 species

ADDITIONAL NOTES ON SUMMER BIRDS OF TURKEY RUN STATE PARK.

Frederick H. Test, West Lafayette.

During the summer of 1928, nature guides were again stationed at Turkey Run Park by the State Department of Conservation. The following observations were made by the same group as last year, Sidney R. Esten, Otto Behrens, Jr., and the writer, and extended over the period from June 11 to August 24. Two new tracts of land had been added to the park in the past year, one of cultivated ground and the other wooded, so that the total park area is now 1,080 acres. However, not many new or unusual observations were made in the new parts. There was an unusually large amount of rain the earlier part of the summer, but the latter part was normal.

Eight new species were added to the list of 1927, raising the total number of species observed nesting in or near Turkey Run to 80. Although the actual nests and young were found of only half this number, the indications are that all the others in the list, with the possible exception of the bald eagle, nested at Turkey Run. This summer the nests or young of 12 species were found that were not observed in 1927. However, three species seen last year were not observed this summer.

Following is a list of summer resident species which were either not observed in 1927 or about which new observations were made.

228. *Philohela minor.* American woodcock. None were noted this summer although the place where the one was found last year was visited several times.

331. *Circus hudsonius.* Marsh hawk. No marsh hawks were seen near the park during the summer.

332. *Accipiter velox.* Sharp-shinned hawk. One was seen on Aug. 24, flying over a field just outside the park by Otto Behrens, Jr. and the writer.

333. *Accipiter cooperi.* Cooper hawk. None were seen near the park.

352. *Haliaeetus leucocephalus.* Bald eagle. The eagle was again noted several times, both by the park superintendent and by the guides.

365. *Aluco pratincola.* Barn owl. One was reported on August 1 by some visitors to the park, who said it was sitting in a tree along Trail 1, near a farm house. Mr. Esten, who questioned the men thoroughly, thought that the record should stand.

368. *Strix varia.* Barred owl. Although this species was evidently much less common than the great horned owl, it was heard several times during the summer.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

423. *Chaetura pelagica.* Chimney swift. Again this summer there were several pairs around the hotel and some probably nested in a rather large chimney back of one of the cottages, as they were several times seen entering it. On one of the early morning bird hikes the writer saw a chimney swift dodge down a hollow beech stub about 15 feet high, which stood near the edge of the hotel grounds. On investigating not long afterward we found a nest containing three eggs about six feet from the top of the stub. The nest and eggs and the stub were photographed and at the end of the summer the nest was collected with the section of the stub to which it was attached.

467. *Empidonax minimus.* Least flycatcher. This species was much less common than the acadian, being identified only a very few times by Mr. Esten.

498. *Agelaius phoeniceus.* Red-winged blackbird. Seen in the county by S. R. Esten, and Charles Kirk, living just outside of Turkey Run, stated that he had often observed them flying past his house during the summer. Probably nested not far from the park.

540. *Pooecetes gramineus.* Vesper sparrow. Seen frequently in the fields in and near the park.

546. *Ammodramus savannarum australis.* Grasshopper sparrow. Rather infrequent. A few were heard in the fields back of the garage and in the old Hockett tract.

604. *Spiza americana.* Dickcissel. Several were heard and seen in the fields within two or three miles of the park.

610. *Piranga rubra.* Summer tanager. A nest of this species was found about 25 feet above the ground on a limb of a large white oak which stood just back of the cottages. This was the only pair observed during the summer.

639. *Helmitheros vermivorus.* Worm-eating warbler. Heard and seen infrequently throughout the summer.

675. *Seiurus motacilla.* Louisiana water-thrush. Fairly common. A nest was found on the ground among the leaves at the base of a hill which contained three young cowbirds but no water-thrushes. Near Trail 7, a young cowbird and a young water-thrush being fed by the adult water-thrush were caught. The three cowbirds and the water-thrush were banded.

677. *Oporornis formosa.* Kentucky warbler. Although none were noted in 1927, they seemed to be almost frequent this summer, several pairs being seen in the bottom lands. One nest, made of leaves and containing five young, was found at the base of a small pawpaw tree near an old trail in the bottoms along the river. All the young were banded.

683. *Icteria virens.* Yellow-breasted chat. Rather rare. One could usually be found in one or two swampy places of the park.

718. *Thryothorus ludovicianus.* Carolina wren. Common. Two nests, both made of leaves, were found. One was under the eaves in the pump house and was reached through an open window. In three or

four other places under the eaves there were small piles of leaves, evidently unfinished nests. The other was about six feet above the ground in a grape vine only about 20 feet from one of the trails.

751. *Polioptila caerulea.* Blue-gray gnatcatcher. These birds were seen frequently this summer, usually in groups of two or three. Three nests were found. One containing young was near the top of a tall dead elm by the suspension bridge. Not observed in 1927.

Birds Which Probably Nested in the County but Not Near the Park.

77. *Hydrochelidon nigra surinamensis.* Black tern. Two were seen on July 19, by Louis A. and Frederick C. Test, flying over a pond near State Road 41 just inside the county and about ten miles from Turkey Run. The pond seemed to be only a rain pond and it was not determined whether or not they nested in the county.

494. *Oolichonyx oryzivorus.* Bobolink. Seen in the county on June 26 by S. R. Esten.

A PRELIMINARY REPORT ON LERNAEA, A COPEPOD PARASITIC ON THE GOLDFISH.

H. E. Enders and S. A. Rifenburgh, Purdue University.

Lernaea has been reported previously[1] as parasitic on some 20 or more species of fishes, but so far as we have learned, no one has reported it on the goldfish.

In the autumn of 1928 our attention was called, by the officials of a large fishery in Indiana, to so-called "fish lice" on their goldfish which were the cause of considerable mortality among fish of salable size resulting in serious financial losses. These parasites have been shown to be members of the family Lernaeidae and genus Lernaea. They are found anchored in the flesh of the fish usually at the base of one of the fins and projecting backward from the point of attachment for 10 mm. or less. The anchor consists of four horn-like outgrowths from the cephalothorax two of which are usually branched. Near the distal end of the parasite two egg sacs may be attached. These are about 3 mm. in length and contain dozens of eggs in two or more rows.

Investigations are in progress to determine the life history and methods of control. The egg sacs are removed from a parasite and placed in water in a Syracuse watch glass which is then covered to prevent evaporation. Sacs may be removed repeatedly from the same parasite at intervals of two or three days.

Results thus far obtained indicate that the life history of this species follows the type for the genus. About three days after the appearance of egg sacs the eggs hatch into oval nauplii .12 mm. in length with three pairs of appendages. These swim about jerkily for a few hours, then in less than a day molt and become metanauplii. The metanauplii are also provided with three pairs of appendages but show a change in shape from the nauplius form, being now pear-shaped, .15 mm. in length and with a pair of spines on the sides.

The larvae remain in the metanauplius stage about four days, at room temperature, and molt again. After this second molt their appearance is considerably changed, showing now several free segments and seven pairs of appendages. They are now about .25 mm. in length and correspondingly less in breadth than the metanauplii since they have taken no food thus far. The second antennae and the maxillipeds are provided with claws which suggests that they are ready to attach themselves to a host. This is the first copepodid stage. They die in three to five days, in cultures not supplied with food. All the stages previously mentioned are free-living in the water.

[1] Wilson—Economic Relations, etc., of genus Lernaea. Bull. U. S. Bur. Fish., *35*, pp. 163-198, 1915-16.

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

This is as far as we have traced the life history thus far. If the life history of this species is similar to that of other species of Lernaea, we expect to be able to get the copepodid larvae to attach temporarily to the gills of a fish, and molt three more times before copulation occurs, after which the female seeks out her final location and anchors at the base of a fin.

RECORDS OF INDIANA DRAGONFLIES, III. 1927-1928.

B. ELWOOD MONTGOMERY, Iowa State College.

During the years 1927-1928, about 3,040 specimens of dragonflies, representing 74 species were collected in Indiana. Although most of these have been collected by Mr. E. B. Williamson and the writer, one or both of whom were on almost every collecting trip contributing to this collection, many others have assisted; J. H. Williamson, Lloyd Cowens and Paul Cook accompanied Mr. Williamson frequently and made many captures; Robert F. Sazama, John Warrick Emerson, J. Byers Hunley, Robert W. Montgomery, Boner and Esther Barrett have each aided me on one or more collecting trips and Mr. Sazama made several excursions alone.

New county records, captures of rare species and notes on certain habitats and associations are recorded here. Field notes, which have been copied without change, are placed within quotation marks and are followed by the initials "E. W. B." or "B. E. M.", indicating whether Mr. Williamson or the writer made the observations.

Vanemon Swamp, near Bluffton, Wells County, has been under observation by Mr. Williamson for many years; the condition of the swamp, changes from year to year, and the dragonfly fauna have been noted in previous papers (1921), (1925), (1927). Mr. Williamson, accompanied by J. H. Williamson and Harry Dietz, visited the swamp June 9, 1927, and made the following notes.

"Visited Vanemon Swamp about 8:30-11:30 a. m. Day bright and warm—favorable. *Lestes* spp. (teneral, in great numbers), *Ischnura verticalis, I. posita, Agrion maculatum* (two females in brush, doubtless strays); *Erythemis simplicicollis, Pachydiplax longipennis. Leucorhinnia intacta,* numerous; *Libellula pulchella,* rarer; several male *Epiaeschna heros* soaring high over swamp (20-30 feet). Tetragoneuria, one male seen for a few beats back and forth, then disappeared and did not see again; doubtless a stray. Visited nearest gravel pit (McCleery's) and J. H. W. caught two Tetragoneurias (*cynosura* and *simulans.* B. E. M.) there. At Vanemon Swamp no Tramea, Anax, Aeshna or Enallagma seen. Water very high, many turtles and a few large frogs. Spatterdock greatly increased in area since 1926—due doubtless to several wet seasons it seems greatly on increase. Prothonotary warblers (at least two pairs) noticed for first time at swamp. Today is first record of a Corduline at the swamp—a Tetragoneuria, probably one with reduced black at wing base. At McCleery's pit saw Tetragoneuria, *Libellula luctuosa, L. pulchella, Tramea lacerata, Plathemis lydia, Ischnura verticalis, Enallagma antennatum,* and *E. civile,* (other species may have been there as we were at pit only a few minutes)."

"Proc. Ind. Acad. Sci., vol. 38, 1928 (1929)."

I visited the swamp September 9, 1928. *Lestes congener*, males abundant, a few females; *L. rectangularis, L. unguiculatus* present in small numbers; *Ischnura posita, Anomalagrion hastatum*, one female of each; *Sympetrum rubicundulum*, common. Water was rather low, margin muddy.

J. Byers Hunley and the writer visited a water supply reservoir, near Oakland City, July 29, 1928. This reservoir which was constructed two years ago covers an area of 25 acres. The margin is very irregular and low hills surround the water on all sides except the south. Vegetation is sparse and low on the hill sides except for a few thickets of brambles. The shores are bare clay or rocky; a few small clumps of cattails were noted. Collecting was done on the north and west sides only. An attempt was made to secure all the species occurring and representatives of all seen, except *Epicordulia princeps*, were taken. *Enallagma civile* were rather numerous, *Ischnura verticalis* common, *Epicordulia princeps* were patrolling the shores; *Libellula luctuosa* was very common, many tenerals; many *Perithemis tenera*, males and females, were taken on the hill sides back from the water, males were seen over the water; a female each of *Erythemis simplicicollis* and *Sympetrum vicinum* seen and captured; a few *Pachydiplax longipennis*, many *Celithemis elisa*, a few *C. eponina;* two very teneral *Tramea lacerata* were captured.

In former notes (1925), (1927), I have recorded captures at a body of water, which I called "Lotus Pond," near Decker, Knox County. This pond covers some seven or eight acres; it is located in a region of sandy soil. Except for a narrow strip in the center, extending the full length of the pond, and a shallow area at the south and separated from the remainder of the pond by a fence, there is a thick growth of water smartweed. Nelumbo plants are common, especially near the open water in the center of the pond. During July and August the greatest depth of water found during the four years that I have visited the pond was not more than thirty inches and most of the area filled with vegetation was covered with less than 10 inches of water. In April I have found the water about 10 to 12 inches higher and in very dry seasons about half of the area may be free from water. The east side of the pond is bordered with trees, chiefly willow. The field containing the pond is sometimes pastured but animals do not seem to invade the pond itself to any great extent; the shallow area at the south end is part of a barn lot. The water is very rich in invertebrate life; fish or other aquatic vertebrates have not been noted, although a careful search was never made. Twenty-two species have been recorded from this pond.

Lestes eurinus, L. forcipatus, L. rectangularis, L. unguiculatus, Enallagma aspersum, E. civile, E. geminatum, E. hageni, E. signatum, Nehalennia irene, Ischnura posita, I. verticalis, Anomalagrion hastatum, Anax junius, Libellula luctuosa, L. pulchella, Plathemis lydia, Erythemis simplicicollis, Sympetrum vicinum, Pachydiplax longipennis, Tramea carolina, T. lacerata, T. onusta.

Not all of these have been taken at one time; many of them have

been taken only once. This list is not at all complete and continued collecting will likely disclose several other species in favorable seasons, but this gives an idea of the species able to perpetuate themselves in an area under cultivation. *I. posita* and *P. longipennis* were the dominant species, both present literally by the thousands, but the latter was the more conspicuous. Many *E. simplicicollis* were present at all times during the summer of 1928, tenerals resting in the vegetation, females ovipositing in the open water or in small pools of water contained in the center depression on the upper surface of Nelumbo leaves, males dashing at *P. longipennis* or, by twos, executing the peculiar evolutions described by Williamson (1899). Several individuals of *A. junius* were always seen, soaring over the pond at varying heights. The vegetation was usually filled with *I. posita, I. verticalis* and *Lestes* spp.; *A. hastatum* was sometimes associated with these. One or more species of Enallagma were usually found over or at the margin of open water, but individuals of this genus have not been numerous here at any time during the period of observation. *L. pulchella, L. luctuosa,* and *P. lydia* were common, especially near the south end of the pond; an individual seen here in 1924 was determined as *Libellula incesta* by S. W. Bromley and the writer, but no capture was made. *T. lacerata* has been present each year, at times in considerable numbers; *T. carolina* and *T. onusta* have been taken—one record for each.

Foote's Lake is a body of water about two miles long and 100-300 yards wide, in Gibson County, three miles from the Wabash River. At times of high water in the lower Wabash Valley this lake is reached by the overflow water; there is said to be a decided current in the lake at such times. One side of the lake is bordered by wooded "bottomland" and brush grows to the water margin; the other shore is bordered, partly by cultivated fields separated from the lake by a narrow margin of trees and partly by high hills, wooded and somewhat rocky, rising directly from the lake. The bottom of the lake at the foot of the hills is rocky; at this point the water is quite deep (20 feet or more) but in other parts of the lake the depth is considerably less. Spatterdock beds are extensive.

Macromia taeniolata has been found here every year since 1924; *Nasiaeschna pentacantha* has been observed a number of times; *Dromogomphus spoliatus* is rather common at the foot of the hills; *Agria apicalis* and *A. tibialis* have been taken at the same place; *Gomphus submedianus* has been collected at the lake on three occasions and seen at other times. Other species, as follows, have been taken.

Lestes rectangularis, Enallagma civile, E. exsulans, E. vesperum, E. signatum, E. traviatum, Ischnura posita, I. verticalis, Epicordulia princeps, Libellula incesta, L. luctuosa, L. pulchella, Plathemis lydia, Perithemis tenera, Erythemis simplicicollis, Pachydiplax longipennis.

Byers (1928) has shown that dragonflies which are destroyed by automobiles are members of the strong-flying groups of "wanderers." Three species, all of this type, in the present collection were taken by this most modern insect collector; an *Anax junius* was taken when it flew or was carried by air currents into a car, a female *Epiaeschna*

heros alighted on the hood of a car in motion and remained until secured as noted below, a female *Pantala hymenaea* was secured from the radiator of a car and another of the same species was found dead in a car after a long drive.

Several species of dragonflies were representated in a small collection of insects which the writer saw at Benjamin Bosse High School, Evansville; these were said to have been collected at a small pond in Evansville during the summer of 1926 by Georgine Koser. Records from this collection are indicated by the initials "B. B. H. S."

The order and numbers used in Williamson's list (1917) are followed here.

3. *Agrion maculatum* Beauvois. Captured at several creeks in Knox Co., during July and August, 1928. A male taken July 21, is the smallest of this species which I have seen (abd. 32 mm., f. w. 25 mm., r. w. 24.5 mm.). Vanderburg Co. (B. B. H. S.)

4. *Hetaerina americana* Fabricius. Mississinewa River, west of Albany, Delaware Co., Aug. 22, 1927; along Wabash River and creeks in Gibson and Posey counties, July and Aug., 1927; Wabash River and creeks in Knox Co., July and Aug, 1928; pond, three miles south of Pimento, Vigo Co., July 15, 1928.

6. *Lestes congener* Hagen. Gravel pit, near Pennville, Jay Co., Aug. 22, 1927; Cedar Lake, Whitley Co., Sept. 5, 1928.

9. *Lestes forcipatus* Rambur. Pond about three miles north of Poseyville, Gibson Co., June 2, 1928.

11. *Lestes rectangularis* Say. Gravel pit, near Pennville, Jay Co., Aug. 22, 1927.

13. *Lestes unguiculatus* Hagen. Swamp, near Cowan, Delaware Co., Aug. 22, 1927; Lotus Pond, Knox Co., Aug. 2, 13, 1928.

15. *Argia apicalis* Say. Bayou, near Wabash River, Vigo Co., Aug. 21, 1927; Mississinewa River, west of Albany, Delaware Co., Aug. 22, 1927; Busseron Creek, near Paxton, Sullivan Co., July 15, 1928.

16. *Argia moesta* Hagen. Mississinewa River, west of Albany, Delaware Co., Aug. 22, 1927; Wabash River, Gibson Co., July 27, Aug. 5, 1927; Pigeon River, west of Howe, Lagrange Co., Aug. 28, 1927; Wabash River, Posey Co., Aug. 10, 12, 1927.

17. *Argia sedula* Hagen. Mississinewa River, west of Albany, Delaware Co., Aug. 22, 1927; creek, four miles south of Vincennes, July 18, 1928; Black River Creek, Posey Co., Aug. 7, 1927.

18. *Argia tibialis* Rambur. Mississinewa River, west of Albany, Delaware Co., Aug. 22, 1927; creek about two miles north of Vincennes, July 21, 1928; Black River Creek, Posey Co., July 31, Aug. 7, 10, 1927.

20. *Argia violacea* Hagen. Black River Creek, Gibson Co., July 25, 1927; gravel pit, near Pennville, Jay Co., Aug. 22, 1927; swamp, three miles south of Wadesville, Posey Co., July 28, 1927.

21. *Enallagma antennatum* Say. Pond, three miles south of Pimento, Vigo Co., July 15, 1928.

22. *Enallagma aspersum* Hagen. Small ponds in several localities in Gibson Co., July 24, 1927, May 25, July 29, 1928; Lotus Pond, Knox Co., July 18, 1924, July 24, 1927, July 27, Aug. 3, 13, 22, 1928.

24. *Enallagma carunculatum* Morse. Wabash River, Gibson Co., Aug. 31, 1926.

25. *Enallagma civile* Hagen. Gravel pit, near Pennville, Jay Co., Aug. 22, 1927; many localities in Posey Co., from July 28 to Sept. 3, 1927; Vanderburg Co. (B. B. H. D.)

29. *Enallagma exsulans* Hagen. Mississinewa River, west of Albany, Delaware Co., Aug. 22, 1927; gravel pit near Emison, 1928; creeks, Knox Co., July 18, 20, 21, Aug. 5, 1928.

30. *Enallagma geminatum* Kellicott. Reservoir, Oakland City, Gibson Co., May 26, 1927.

31. *Enallagma hageni* Walsh. Reservoir, Oakland City, July 29, 1928; Lotus Pond, Knox Co., July 28, 1928.

34. *Enallagma signatum* Hagen. Bayou near Wabash River, Vigo Co., Aug. 21, 1927.

36. *Nehalennia gracilis* Morse. This and the following species were objects of special search during the two seasons; although both are rare in Indiana they were taken on a number of occasions, usually associated with each other. At Case Lake, Lagrange Co., July 24, 1927, two males and one female of *gracilis* and eight males of *irene* were taken; one male of *gracilis* was captured along Pigeon River, west of Howe, Lagrange Co., Aug. 28, 1927. One male, five females of *gracilis* and two males, four females of *irene* were collected at Huffman Lake, Steuben Co., August 25, 1927; these were found within a limited area, probably 400 square feet, somewhat boggy, water about one to two inches deep and grown up with Scirpus, the common pitcher plant and other bog plants.

37. *Nehalennia irene* Hagen. In addition to the captures given under the preceding this species was found at two other localities, at Wall Lake, Lagrange Co., July 24, 1927, one male, and at Lotus Pond, Knox Co., July 27, four males, four females, July 28, seven males, nine females, Aug. 2, 1928, one male, one female. At the latter locality it was taken within a very limited area, about 30 feet in diameter, where the water was about six inches deep and the growth of water smartweeds reached a height of 20 to 25 inches; although these conditions of vegetation and water extended over several acres, and *Ischnura posita* and *I. verticalis*, with which it was associated, were numerous throughout, careful search disclosed none of this species elsewhere.

40. *Ischnura kellicotti* Williamson. Case Lake, Lagrange Co., Aug. 24, 1927.

41. *Ischnura posita* Hagen. Swamp, near Cowan, Delaware Co., Aug. 22, 1927; gravel pits, creeks and ponds in many parts of Knox Co., from June 20 to Aug. 29, 1928; pond in Evansville, Vanderburg Co., May 23, 1928; pond near Pimento and bayou along Wabash River, Vigo Co., Aug. 21, 1927. In southern Indiana I have found this almost as common and in many localities more numerous, than *I. verticalis* but in the northern counties I have not seen it in as many localities nor as numerous as the latter species, where it does occur.

43. *Ischnura verticalis* Say. Gravel pit, Pennville, Jay Co., Aug. 22, 1927; pond, Evansville, May 23, 1928; pond, Pimento, Aug. 21, 1927.

44. *Anomalagrion hastatum* Say. Lotus Pond, Knox Co., July 24, 1927, July 27, 28, 1928; Black River Creek, Posey Co., July 28, 1927; Huffman Lake, Steuben Co., Aug. 25, 1927; pond three miles south of Pimento, Vigo Co., July 15, 1928.

49. *Progomphus obscurus* Rambur. Black River Creek, four miles north of Poseyville, Gibson Co., July 23, 25, 1927; along Pigeon River, four miles above Mongo, Lagrange Co., July 3, 1927. "A male taken along stream south of Goshen, probably in Kosciusko County, July 10, 1927. Stream 12 to 20 feet wide, swift and deep. Several seen, resting on logs in stream. This individual flew along stream and alighted on vertical twig in a dead cornus bush—only time I ever saw *obscurus* on a twig." E. B. W.

50. *Hagenius brevistylus* Selys. Pigeon River, four miles above Mongo, July 3, 1927; Pigeon River, west of Howe, Lagrange Co., Aug. 28, 1927.

52. *Erpetogomphus designatus* Hagen. Wabash River, six miles below New Harmony, Posey Co., Aug. 12, 1927.

56. *Gomphus fraternus* Say. Pigeon River, four miles above Mongo, Lagrange Co., July 3, 1927.

63. *Gomphus submedianus* Williamson. This species was found again at Foote's Lake, Gibson Co., in 1927, a male was taken July 26 and a female July 31. "A number of this species seen, usually resting on leaves floating flat on surface of water. Now and then one would take a wide flight over the water or less frequently above the trees along the shore. They were very wary and exceedingly difficult to take; only one captured," July 26, 1927. B. E. M.

68. *Dromogomphus spinosus* Selys. Sand Lake, Noble Co., Aug 27, 1928. "On spatter-dock beds. Rare; only two seen in complete circle of lake." E. B. W.

70. *Boyeria vinosa* Say. Mississinewa River, west of Albany, Delaware Co., Aug. 22, 1927; Wabash River, three miles south of Griffin, Posey Co., Sept. 3, 1927; Vanderburg Co. (B. B. H. S.) The male taken along the Wabash was flying high and rather wildly, dashing in one direction for a short distance, then in another, when first seen. It finally came to rest on the trunk of a small tree, about 15 feet from the ground, in a willow thicket, several feet back from the water.

"A female taken in dense low woods, flying about like a Gynacantha; male about boats at landing after sundown flying about also like a Gynacantha." Sand Lake, Noble Co., Aug. 26, 1928. E. B. W.

72. *Anax junius* Drury. Wall Lake, Lagrange Co., July 24, 1927.

75. *Aeshna constricta* Say. Aboite River, three miles north of Aboite, Allen Co., August 7, 1927.

78. *Aeshna umbrosa* Walker. Over field, four p. m., near Sand Lake, Noble Co., Aug 26, 1928.

79. *Aeshna verticalis* Hagen. Mating pair taken at a marsh, one mile south of Mt. Pisgah, Lagrange Co., Sept. 4, 1928. During the latter part of August and the early part of September of both years special attention was given to hunting for Aeshnas, but only four individuals were taken and few others seen, in localities where many have been taken in former years.

80. *Nasiaeschna pentacantha* Rambur. Pigeon River, four miles above Mongo, Lagrange Co., July 3, 1927; Sand Lake, Noble Co., Aug. 25, 1928.

81. *Epiaeschna heros* Fabricius. Winslow, Pike Co., July 3, 1928. Alighted on hood of auto about dusk, remained until car was stopped and a jar in which to place the dragonfly was secured. Specimen and notes furnished by Claude Smith. Five individuals of this species were taken in houses in Bluffton, April 17, 23, 1927.

85. *Macromina taeniolata* Rambur. Footes' Lake, Gibson Co., July 26, three males, one female; July 31, one male; Sept 1, nine males, three females; Sand Lake, Noble Co., Aug. 28, 1928, three males; Black River Creek, three miles north of Poseyville, Posey Co., Aug. 7, 1927, six males; Hovey's Lake, Posey Co., Aug. 12, 1927, two males. "The female was ovipositing, flying about over the spatter-dock bed and occasionally dipping down between the leaves and striking her abdomen against the water." July 26, 1927. B. E. M. "Three altogether, patrolling northwest side along woods. Beats varied in length. Not wary but were difficult to catch from a boat; best way is to fasten boat at some far-projecting vegetation, drooping willow or vine-covered bush, and await the dragonflies." Aug. 28, 1928. E. B. W.

87. *Epicordulia princeps* Hagen. Lake south of Plato, Lagrange Co., July 22, 1928; Wabash River, Posey Co., August 10, 1927; Hovey's Lake, Posey Co., Aug. 12, 1927. Two females, each carrying a mass of eggs, were taken at Foote's Lake, Gibson Co., July 31, 1927. The posterior portion of the abdomen was curved upward and forward forming a semicircle and the eggs were held in place beneath the vulvar lamina at the highest point of this curve. The egg masses were spherical, about six or seven millimeters in diameter; when placed in water the masses absorbed water rapidly, soon assuming a flat disc shape, about 25 mm. in diameter and three millimeters thick. The masses were covered with a growth of green algae within a few days, but hatched at the end of 15 days.

99. *Libellula luctuosa* Burmeister. Gravel pit, near Pennville, Jay Co., Aug. 22, 1927; pond, Pimento, Aug. 21, 1927; pond, three miles south of Pimento, Vigo Co., Aug 21, 1927, July 15, 1928.

100. *Libellula pulchella* Drury. Gravel pit, near Pennville, Jay Co., Aug. 22, 1927; pond, three miles south of Pimento, Vigo Co., Aug. 21, 1927.

104. *Plathemis lydia* Drury. Pokagon State Park, Steuben Co., July 24, 1927; Vanderburg Co. (B. B. H. S.); pond, three miles south of Pimento, Vigo Co., Aug. 21, 1927.

105. *Perithemis tenera* Say. Common along Wabash River and at ponds and marshes in Posey Co., captured on many dates between July 26, and Sept. 17; Hogback Lake, Steuben Co., Aug. 25, 1927; pond Pimento, Vigo Co., Aug. 21, 1927.

106. *Nannothemis bella* Uhler. A special search for this species was made in 1927, resulting in the capture of one female at Case Lake, Lagrange Co., July 24, and 14 males, five females at Huffman Lake, Steuben Co., Aug. 25, 26. At the latter locality the species was confined to the small area described above under No. 36, *Nehalennia gracilis.*

This area was examined carefully and I believe the 19 individuals taken made up the entire population of the species. They were difficult to see, usually resting on stalks of Scirpus and when disturbed flew quickly to another stalk never rising to the top of the vegetation.

107. *Erythemis simplicicollis* Say. Gravel pit, near Pennville, Jay Co., Aug. 22, 1927; various localities in Lagrange Co., July 24, 1927, July 22, Sept. 4, 1928; pond, Pimento, Aug. 21, 1927, pond three miles south of Pimento, Vigo Co., July 15, 1928.

"Female was eating a still living *Sympetrum vicinum,* female, teneral, when captured," July 22, 1928. E. B. W.

108. *Sympetrum ambiguum* Rambur. This rare species was found in an orchard, far from water, at Pimento, Vigo Co., Sept. 1, 1928. Several individuals were seen, but were wary and quick in flight so that only two were taken.

112. *Sympetrum rubicundulum* Say. Swamp, near Cowan, Delaware Co., Aug. 22, 1927; gravel pit, near Pennville, Jay Co., Aug. 22, 1927; orchard, near Decker, Knox Co., July 10, 1928. The female taken July 10, 1928, was eating a tarnished plant bug (*Lygus pratensis* Linn.).

113. *Sympetrum semicinctum* Say. Several localities in Lagrange Co., July 24, Aug. 28, 1927, July 22, 29, Sept. 4, 1928, a total of 16 individuals; Pokagon State Park, Steuben Co., July 24, 1927; small lake north of Snow Lake, Steuben Co., Aug. 26, 1927.

114. *Sympetrum vicinum* Hagen. Reservoir, Oakland City, Gibson Co., July 29, 1928.

115. *Pachydiplax longipennis* Burmeister. Gravel pit, near Pennville, Jay Co., Aug. 22, 1927.

118. *Celithemis elisa* Hagen. Reservoir, Oakland City, Gibson Co., May 26, 1927, July 29, 1928; gravel pit, near Pennville, Jay Co., Aug. 22, 1927.

119. *Celithemis eponina* Drury. Reservoir, Oakland City, Gibson Co., July 29, 1928.

120. *Celithemis monomelaena* Williamson. Wall Lake and Case Lake, Lagrange Co., July 24, 1927. (At Case Lake). "In low vegetation back from the lake, beat down by wind. When flushed wind whipped them away." E. B. W.

122. *Pantala hymenaea* Say. Vanderburg Co., (B. B. H. S.); a female of this species was taken from the radiator of an automobile, which had just been driven from Rockville to Terre Haute, July 15, 1928.

123. *Tramea carolina* Linne. Lotus Pond, Knox Co., May 8, 1927.

124. *Tramea lacerata* Hagen. Reservoir, Oakland City, Gibson Co., July 29, 1928; Black River Creek, three miles north of Poseyville, Posey Co., July 23, 1927. This species was very abundant at Lotus Pond, Knox Co., July 28, 1928; many pairs were in copulation and oviposition was observed; the male releases the female and hovers above her while she strikes her abdomen against the surface of the water a few times, and recaptures her as she rises, first grasping her head with his feet, then bending the abdomen to regain hold with appendages. Forty-two males and 17 females were captured.

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*Davis, John J., Purdue University, W. Lafayette.....M20, F24
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*Deam, Charles C., Bluffton.....M00, F10
Dean, John C., University Club, Indianapolis.....M14
Demaree, Delzie, University of Arkansas, Fayetteville, Ark.....M20
Deppe, C. A. Franklin.....M11
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*Dietz, Harry F., State House, Indianapolis.....M09, F22
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Doan, Richard L., Reed College, Portland, Oregon.....M22
Dolan, Joseph P., Syracuse.....M95
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Douglass, Benj. W., Trevlac.....M16
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Emerson, John D., Ligonier....M25
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Francke, Harry, Henryville....M28
Frazier, Jesse M., Sulphur Springs....M23
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Garregies, John Paul, Brazil....M26
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Hills, Donald C., 532 W. 31st St., Indianapolis....M22
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Hoffman, Ira C., 445 Vine St., W. Lafayette (I)....M24

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Holl, Dr. Carl Waldo, North Manchester....M26
Holloway, Ancil D., Fairmount....M28
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Hooper, Florence, Iowa State College, Ames, Iowa....M24
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Hoskins, John Hobart, Univ. Cincinnati, Cincinnati, Ohio....M27
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Howick, Howard, Ball Teachers College, Muncie....M21
Howlett, Berton A., 2217 S. 7th St., Terre Haute....M19
Huber, Leonard L., Hanover College, Hanover....M15
Hufferd, Ralph, Greencastle....M20
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Hufford, Gayle N., 216 Seeser St., Joliet, Ill....M26
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Hull, Daniel, Univ. Notre Dame, Notre Dame....M27
Hunt, Herschel, Hazleton....M28
Hunt, Raymond S., Empire Oil & Refg. Co., Dept. of Geology, Bartlesville, Okla....M23
Hunter, Mrs. Stephen, 2832 Highland Ave., Cincinnati, Ohio....M25
Huston, Ernest C., R. R. 4, Pekin....M28
Hutchinson, Emory, Norman Station....M25
Hutton, Joseph G., State College, Brookings, S. D....M11
Hyatt, George F., 140 W. Sheridan St., Greensburg....M25
Hyslop, George H., 116 E. 63rd St., New York City, N. Y....M14
Inskeep, Anna M., Monticello....M24
Irons, Vernal, Jasonville....M
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Jackson, Jas. Wm., Central H. S., Chattanooga, Tenn....M18
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Kaczmarek, Regidius M., Notre Dame Univ., Notre Dame....M14

Kaley, Leona M., Bremen....M23
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Kaylor, J. F., Dept. Conservation Div. Forestry, Indianapolis....M27
Keipper, Charles Homer, Dept. Biology, Purdue Univ., W. Lafayette....M24
Kellogg, Mary, Boswell....M23
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Kendrick, James B., Agric. Exp. Sta., Davis, Calif....M21
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*Kern, Frank D., State College, Pa....M05, F12
Kiesling, Norman, R. R. 1, Logansport....M28
King, Florance, B., 809 E. Tenth, Bloomington....M28
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Kinnet, Russell, Milroy....M23
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Kline, James Edward, Notre Dame Univ., Notre Dame....M27
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Lambertson, Margot G., Moores Hill....M27
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Leamon, Grace, Stockwell....M24
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Leer, Wayne E., 349 W. Thornell, W. Lafayette....M24
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Lefler, Glenn Q., Warren....M28
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Lehman, Rachel Marguerite, R. R. 2, Brazil....M28
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Liston, Jesse G., R. F. D. 2, Lewis....M16

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Moznigo, Paul Payne, Franklin Food Products Co., Franklin M24
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Mullendore, Naomi, Franklin M22
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Murch, Rev. Raymond Martin, Notre Dame M27
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Myers, Raymond J., R. R. 3, Republic, Ohio M28
Navarre, Alfred T., 708 N. Hamilton, Flint, Mich. (I) M27
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Neff, Joseph Edgar, 132 S. Scott, South Bend M23
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Nester, Henry George, 2832 N. Capitol, Indianapolis M23
Newsom, Clara Mary, Elizabethtown M28
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Owen, Mrs. Marjorie Blake, 2202 Portage Ave., South Bend M28
Packard, C. M., Box 495, W. Lafayette M26

Paff, George H., 1126 Sixth Ave., Beaver Falls, Pa.....M28
Painter, Henry R., Box 495, W. Lafayette.....M21
Painter, Louise, Springport.....M26
Palmer, C. M., Butler University, Indianapolis.....M25
Parfitt, Elliott H., 1025 Third St., W. Lafayette.....M23
Paschen, Everett Herman, Box 172, Buckley, Ill.....M24
*Payne, Fernandus, 620 Ballantine Road, Bloomington.....M13, F16
Pearce, Joseph Roberts, Willow Hill, Ill.....M24
Pearson, Nathan Everett, Dept. Zoology, Butler University, Indianapolis.M22
Peddle, John B., Rose Polytechnic Inst., Terre Haute.....M25
Pedlow, J. Thomas, 203 Arlington, Greencastle.....M28
Peffer, Harry Creighton, 1022—7th St., W. Lafayette.....M14
Perkins, III, Samuel E., Inland Bank Bldg., Indianapolis.....M27
Perkins, Wendell LeRoy, 1913 S. 10th St., Terre Haute.....M25
Petry, Edward J., 716 Scott St., Conway, Arkansas.....M11
Philbrick, Shailer S., 2130 Sherman Ave., Evanston, Ill.....M28
Phillips, Alice V., 4906 W. 16th St., Indianapolis.....M28
Pickett, Fermen L., College Station, Pullman, Wash.....M09
Pierce, Arthur Lester, Box 61, Notre Dame Univ., Notre Dame.....M27
Pinkerton, Earl, Box 447, Walters, Okla.....M16
Pinnick, Atha A., East 10th St., Bloomington.....M25
Pitkin, Edward Meyer, Martinsville Sanatorium, Martinsville.....M22
Pittenger, Samuel Arthur, Selma.....M26
Pittenger, John S., 609 E. University St., Bloomington.....M26
Pittman, Lenard E., Fairbanks.....M26
Plummer, Louisa G., 975 North F St., Hamilton, Ohio.....M28
Poffenberger, John, Butler.....M26
Pollard, Cash B., 415 Russell St., Lafayette.....M21
Poorman, Alfred Peter, 329 Russell St., W. Lafayette.....M24
*Porter, Charley Lymar, 484 Northwestern Ave., W. Lafayette.....M23, F28
Post, Ida M. (Mrs.), 920 N. Center St., Terre Haute.....M25
Potter, Andrey A., 1012 Seventh St., W. Lafayette.....M24
Potter, Prilda H., 529 E. First St., Bloomington.....M27
Potzger, John E., 1311 Linden St., Indianapolis.....M26
Powell, G. Maxwell, Mar-Main Arms, South Bend.....M28
Powell, Horace M., 3947 N. Illinois St., Indianapolis.....M26
Powers, Roscoe, R. 6, Box 384, Indianapolis.....M27
Price, Gladys, Route I, Box 68, Rensselaer.....M26
Price, Irene, Rensselaer.....M28
Price, Otho J., 605 Grant, Terre Haute.....M25
Price, J. Waide, 1219 N. Alabama, Indianapolis.....M27
Price, Walter A., Purdue University, W. Lafayette.....M19
Pritchard, Harmon, 357 Downey Ave., Indianapolis.....M27
Quakenbush, Cloyce Verlin, Route 1, Orleans.....M28
Quick, Carl J., 507 Waldron St., W. Lafayette.....M25
Quick, Tunis J., Columbus.....M27
Rabb, Albert L., 1351 Consolidated Bldg., Indianapolis.....M21
Railsback, Fern Lucille, Memorial Hall, Bloomington (I).....M26
Railsback, O. L., 930 Second St., Charleston, Ill.....M24
Ralston, George Wallace, Milford.....M27
Ramsey, Hugh Smith, 615 E. 3rd St., Bloomington.....M28

*Ramsey, Rolla R., 615 E. 3rd St., Bloomington....M04, F06
Randolph, Thorne Fitz, 217 Washington St., Danville....M26
Rankin, Horace, R. F. D. 10, Bloomington....M27
Ransom, Clemie E., 2202 N. Capitol Ave., Indianapolis....M27
†Ransom, James H., James Milliken Univ., Decatur, Ill....F02, NR18
Rauth, Adolph W., Commonwealth Power Co., Jackson, Mich....M25
Rawles, Wm. Post., 415 N. Park Ave., Bloomington....M20
Reagan, Albert B., Queets, Jefferson Co., Wash....M87
Rechenberg, Elizabeth Anna, 805 Lincoln Ave., Valparaiso....M27
Records, Ralph L., Edinburg....M20
Reed, Fredda Doris, 5649 Woodlawn Ave., Chicago, Ill....M25
Reed, Harry J., Purdue University, W. Lafayette....M23
Reeves, June, Converse....M27
Relick, Betty R., 1122 Lincoln Way West, Mishawaka....M27
Remmers, Herman H., 409 Russell St., W. Lafayette....M24
*Rettger, Louis J., 31 Gilbert Ave., Terre Haute....M93, F96
Reynolds, Hazel, 2128 Broadway, Indianapolis....M27
Reynolds, J. J., Notre Dame University, Notre Dame....M27
Richards, Dr. & Mrs. Aute, University of Oklahoma, Norman, Okla....M16
Ricketts, Helen E., 3215 N. Olney St., Indianapolis (I)....M23
Richter, Arthur, 321 E. Fourth St., Bloomington....M26
*Ridgway, Robert, 1030 S. Morgan St., Olney, Ill....M20, F27
Riecken, Wm. E., 7 Oak Hill Ave., Delaware, Ohio....M23
Rifenburgh, S. A., 246 Marstellar St., W. Lafayette....M16
Riley, H. K., Dept. Entomology, Purdue Agr. Exp. Sta., Lafayette....M27
Riley, Katharine, 56 Whittier Place, Indianapolis....M16
Robbins, Charles K., 418 Vine St., W. Lafayette....M27
Roberts, Otis S., 328 S. Grant St., W. Lafayette....M25
Roberts, R. Chester, Dept. of Chemistry, Colgate Univ., Hamilton, N.Y..M19
Robertson, Floyd C., Morgantown....M24
Robertson, Frank S., Ewing, Box 127....M24
Robertson, Geneva, R. 5, Box 68, Kokomo....M27
Robinson, Harold H., Box 129, Culver....M25
Rockne, Knute K., Univ. Notre Dame, Notre Dame....M27
Roehm, John Christian, R. R. 2, White Pigeon, Mich....M24
Rogers, Ruth Anna, Box 22, Clearfield, Pa....M23
Rose, James B., 447 Bosart Ave., Indianapolis....M27
Ross, Oran Edgar, Jr., 1823 Keys St., Madison, Wis....M26
*Rothrock, David A., 1000 Atwater Ave., Bloomington....M98, F06
Rothrock, Henry Shirley, 1000 Atwater Ave., Bloomington....M26
Russell, Wilbur Smith, 2015 S. 8th St., Terre Haute....M25
Samson, R. W., 21 Waldron St., W. Lafayette....M28
Schafer, Pearl Catherine, Bremen....M26
Schlender, Emma, 1919 Ruckle St., Indianapolis....M24
Schnarr, Glenn, 309 S. Meridian St., Winchester....M25
*Schockel, Bernard, State Normal, Terre Haute....M13, F17
Schroeder, Russell Arthur, 314 E. Hanna, Greencastle....M28
Schumacher, Matthew, College of St. Thomas, St. Paul, Minn....M27
Schwarz, A. John, 4218 Cornelius Ave., Indianapolis....M25
Scofield, Robert, Crisman....M28
Scott, J. R. S., P. O. Box 262, Bedford....M24

*Scott, Will, 525 S. Park, Bloomington.....M05, F14
Sears, Cecil (Miss), 437 N. 5th St., Terre Haute.....M28
Sears, Velma Loraine, 1616—15th St., Bedford.....M28
Seaton, Jerome P., 443 Vine St., W. Lafayette.....M24
Settle, Ralph D., Petroleum.....M26
Shaw, Otho, Griffin.....M28
Shaw, R. Wm., 1028 State St., W. Lafayette.....M26
Sheaffer, Frank B., 3816 Byram, Indianapolis.....M27
Shelley, Robert L., 520 W. Miller, Bluffton.....M28
Shepherd, Marston Vincent, Dupont.....M28
Sherman, George W., 304 W. Oak St., W. Lafayette.....M18
Shilts, Walter L., 714 E. Corby St., South Bend.....M27
Shlensky, Morris Ralph, 4723 N. Hermitage Ave., Chicago, Ill. (I).....M23
Shock, N. W., 5733 Kenwood Ave., Chicago, Ill.....M25
Shonle, Horace A., 3493 Birchwood Ave., Indianapolis.....M19
Showalter, Ralph W., Eli Lilly Co., Indianapolis.....M15
Shrock, Robert R., Science Hall, Univ. of Wisconsin, Madison, Wis.....M23
Silvey, Oscar, Wm., College Station, Texas.....M09
Simons, J. Clyde, 2317 Miami St., South Bend.....M28
Simpson, Paul Freund, 700 E. 8th St., Bloomington.....M27
Skelton, Maurice Z., 333 E. Georgia, Brazil.....M25
Skinner, Chas. Henry, Marquette Univ., Milwaukee, Wis.....M25
Skinner, Olind, R. R. 2, Crown Point.....M25
Slavin, Arthur D., 2001 St. Paul St., Rochester, N. Y.....M27
Slick, George R., R. R. B, Box 379, Richmond.....M24
Small, Virginia, 202 Washington Place, Indianapolis.....M26
Smelser, George, Box 159, Earlham.....M27
Smith, Benjamin H., Dept. of Botany, I. S. N. S., Terre Haute.....M25
Smith, Charles Piper, San Jose High School, San Jose, Calif.....M03
Smith, Elmer A., 735 Ninth St., Secaucus, New Jersey.....M26
Smith, Ernest R., 309 Greenwood Ave., Greencastle.....M21
Smith, Geraldine Frances, 5222 Catherine St., W. Philadelphia, Pa.....M23
Smith, John E., R. R. 6, Franklin.....M19
Smith, Norman M., Dillsboro.....M28
Smith, Orrin Harold, 613 Anderson St., Greencastle.....M25
Smith, Cressnall, 2007 Guilford, Huntington.....M27
Smith, Zora Mayo, 202 Sylvia, W. Lafayette.....M24
Smithberger, Andrew, Univ. Notre Dame, Notre Dame.....M27
Snow, Charles Chapman, Williams St. & Fruit Ave., Oakland City.....M27
Snowden, Gale, R. R. 3, Box 33, Huntington.....M26
Sousley, Clarence Piersall, Dept. Math., Rose Poly, Terre Haute.....M25
Southgate, Helen A., Michigan City.....M14
Spangler, Iva, Decatur.....M23
Spencer, Raymond E., Caterpillar Tractor Co., Peoria, Illinois.....M27
Sperry, Theodore M., 501 W. 31st St., Indianapolis.....M28
Spieth, Herman, Charleston.....M26
Spindler, George Washington, 9—37th St., W. Lafayette.....M24
Spitzer, George, Agr. Exp. Sta., Purdue University, Lafayette.....M09
†Springer, Alfred, 312 E. 2nd St., Cincinnati, Ohio.....NR
Springer, H. Stewart, 2913 Broadway, Indianapolis.....M24
Spurgeon, Charles Haddon, 618 Eagle, Terre Haute.....M25

Stacy, Allan R., 1555 Ashland Ave., Indianapolis M21
Stair, Edward C., Purdue University, Dept. Horticulture, Lafayette M24
Stanton, Joseph H., 624 Swan St., Terre Haute M26
Stark, Connie R. (Mrs.), 724 N. 8th St., Terre Haute M25
Steele, Brandt F., 322 E. Kirkwood St., Bloomington M24
Steen, Edwin B., 540 W. 113th St., New York City, N. Y. (I) M24
Steiner, Loren F., Dept. of Entomology, W. Lafayette M27
Stevenson, Rose Anna, 751 E. Jefferson St., Franklin M24
Stock, Orion Louis, Dept. Draw., Rose Poly, Terre Haute M25
Stockdale, Paris, Ohio State University, Dept. of Geology, Columbus, Ohio. M18
*Stoltz, Charles, 311 W. Jefferson Blvd., South Bend M09, F19
Stone, Ralph Bushnell, 615 Russell St., W. Lafayette M14
Strickler, Alvin, Evansville College, Evansville M22
Stratton, Everett F., A. T. O. House, Greencastle M27
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Trueblood, Leota, R. R. C, Terre Haute M25
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Wickwise, George C., Angola M24
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Wright, Howard Ford, Fayette, Ohio M28
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Wright, Mrs. M. B., Greencastle, R. R. 3 ..... M25
Wyatt, Mrs. Ima S., 19 Norman Sve., Evansville M27
Wynkoop, Iris Bonylin, R. R. 4, Frankfort M24
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Young, Herman H., Dept. Psychology, Indiana University, Bloomington M22
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INDEX

PAGE

Abbott, R. B. 279
Addington, Arch R. 247
Algae of Indiana 109
Andrews, F. M. 85, 86, 87, 89
Anomalous Dispersion, Method of Showing 295
Archeological Survey Committee Report 15
Auditing Committee Report 15
Bark Formation 85
Benzyl Alcohol, Oxidation of 197
Biological Survey Committee Report 15
Bird Banding in a Large City and a Small Town 323
Birds of Turkey Run State Park 329
Bloomington Quadrangle, Topographic and Physiographic Features .. 247
Bockstahler, H. W. 133
Brady, J. J. 281
Breeze, Fred J. 23, 243
Briscoe, H. T. 187
Bruce, Edwin M. 171
Bushnell, T. M. 245
Butler, Amos W. 321
Cavern Pictures 201
Chapman, Edgar Kincaid: Memorial 20
Chuck-Will's-Widow in Indiana 321
Clifty Falls State Park, Tufa Deposits 123
Committees for 1928 ..... 5, 6
Committees, Reports of 15
Contents, Table of 2
Contrasts Among Indiana Counties 217
Copepod Parasite of Goldfish 333
Coulter, Stanley 29
Cox, C. F. 35
Crucibulum vulgare, Peridia of 105
Cumings, E. R. 32
Cuprous chloride as a Catalyst for Acetylene 196
Daubenmire, Rexford F. 123
Davis, J. J. 299
Dicus, A. W. 295
Differential Erosion 243
Diseases of Iris and Tulip 93
Donahue, Joseph N.: Memorial 22
Dragonflies of Indiana 335
Eagleson, Walton Vashon 175
Eaton, D. L. 287
Ecology of Turkey Run State Park 165

PAGE
Editor's Report 16
Enders, H. E. 333
Equisetum, Pericycle in the Root of 137
Ericaceæ of Southern Indiana 65
Erigeron annus, Variations 86
Erosion, Differential 243
Esterification in the Presence of Anhydrous Salts 187
Ethylidene glycerol, Formula of 195
Executive Committee 5
Executive Committee Minutes 15
Fellows, New Elected 19
Fibrous Marcasite in Crystalline Calcite 231
Food Value of Tomatoes 159
Foohey, W. L. 195, 196
Formula of Ethylidene glycerol 195
Fungi, New Species 131
Fungi of Indiana 127
Fungi, Reaction to Various Wave Lengths of Light 133
Gantz, Richard A.: Memorial 22
Gardner, Max W. 143
Gasoline, Mileage Obtained from 171
General Session, Minutes of 19
Geological Information from Soil Maps 245
Glenn, Oliver E. 275
Goldfish Parasite 333
Goss, William Freeman Myrick: Memorial 23
Gravitational Stimulus Through Root Tip 87
Hansen, Albert A. 139
Hardy, Russell L. 183
Harrodsburg Limestone, Stratigraphic Units of 233
Heimlich, Louis Frederick: Memorial 29
Helical Brass Spring with Constant Pitch Angle 279
Herbicide, Sodium chlorate as a 139
Hershman, J. B. 269
History of the "Hoodoos," near Mammoth Hot Springs 207
Hole, Allen D. 207
"Hoodoos," near Mammoth Hot Springs 207
Indiana Algae 109
Indiana Dragonflies 325
Indiana Fungi 127
Indiana Insects for 1928 299
Indiana Plant Diseases for 1927 143
Insects of Indiana for 1928 299
Internal Parasites of Poultry 297
Iris Diseases 93
Johnson, Marion A. 137
Kaufmann, Fred 30
Kohl, Edwin J. 30
Lake Wawasee Water Mites 315

PAGE
Lawrence County Soil Map 245
Lernaea, a Parasite of Goldfish 333
Lightning, Natural and Artificial 263
List of Members 345
Lockwood, Lewis B. 105
Logan, William N. 225
Lyons, Robert E. 197
MacGillivray, John H. 159
Magnesium carbonate Prepared from Magnesite 175
Mahin, E. G. 38
Mains, E. B. 93
Malott, Clyde A. 201
Marcasite in Crystalline Calcite 231
Marshall, Ruth 315
Mathers, Frank C. 175, 183
Membership Committee Report 9, 17
Membership List 345
Members, New (See also List of Members, page 345) 9
Memorial: Edgar Kincaid Chapman 20
Memorial: Joseph N. Donahue 22
Memorial: Richard A. Gantz 22
Memorial: William Freeman Myrick Goss 23
Memorial: Louis Frederick Heimlich 29
Memorial: Frank C. Senour 31
Memorial: Joseph Swain 32
Memorial: Frank Casper Wagner 35
Memorial: Emerson Blane Wright 34
Metals and the Microscope 38
Mileage from Commercial Gasolines 171
Miller, J. A. 34
Minutes of Executive Committee 15
Minutes of General Session 19
Minutes of Spring Meeting 8
Mites (Water) of Lake Wawasee 315
Monotropa, Preservation of 103
Monroe County Soil Map 245
Montgomery, B. Elwood 335
New Members. (See also list of members, page 345) 9
New Species of Fungi 131
Nieuwland, J. A. 22, 103, 195, 196
Officers and Committees for 1928 5
Officers, New 19
Officers, Past 7
Orbits of Least Action 275
Oxidation of Benzyl Alcohol 197
Palmer, C. Mervin 109
Parasites of Goldfish 333
Parasites of Poultry 297
Past Officers 7

PAGE
Pericycle in the Root of Equisetum 137
Peridia of Crucibulum vulgare 105
Photography of Sound Waves 287
Phytoecology of Southern Indiana 65
Plant Diseases of Indiana 143
Plants, Preservation of 103
Polarization of Radio Waves 281
Pollen Studies 89
Porter, C. L. 30, 133
Poultry Parasites 297
Preparation of Active Magnesium carbonate 175
Preservation of Plants without Discoloration 103
President's Address 38
Press Secretary's Report 17
Price, Otho J. 297
Program Committee Report 17
Program of Winter Meeting 10
Radio Waves, Polarization of 281
Ramsey, R. R. 21, 281
Reaction of Fungi to Various Wave Lengths of Light 133
Relation of Academy to State Committee Report 17
Report of Archeological Survey Committee 15
Report of Auditing Committee 15
Report of Biological Survey Committee 15
Report of Editor 16
Report of Membership Committee 9, 17
Report of Press Secretary 17
Report of Program Committee 17
Report of Relation of Academy to State Committee 17
Report of Research Committee 17
Report of State Library Committee 17
Report of Treasurer 17
Report of Committees 15
Research Committee Report 17
Rifenburg, S. A. 333
Root Tip Sensitive to Gravitational Stimulus 87
Rust Protection of Iron 183
Schroeder, Russel A. 231
Senour, Frank C.: Memorial 31
Slavin, A. D. 103
Smith, Ernest Rice 231
Sodium chlorate as a Herbicide 139
Sound Waves, Photography of 287
State Library Committee Report 17
Stempel, Jr., Guido H. 197
Stockdale, Paris B. 233
Stratigraphic Units of the Harrodsburg Limestone 233
Studies on Pollen 89
Swain, Joseph: Memorial 32

PAGE
Swanson, Caroline H. 165
Test, Frederick Cleveland 323
Test, Frederick H. 329
Test, Louis Agassiz 323
Thermionic Voltmeter as Applied to High Frequency Measurements 269
Three Cavern Pictures 201
Tomato, Quality and Food Value 159
Topographic Features and the Physiographic Background of the Bloomington Quadrangle 247
Treasurer's Report 17
Trenton Limestone in Indiana 225
Tufa Deposits at Clifty Falls State Park 123
Tulip Diseases 93
Turkey Run State Park Birds 329
Turkey Run State Park Ecology 165
Van Hook, J. M. 127, 131
Variations in Erigeron annuus 86
Variations of the Force Function upon Orbits of Least Action 275
Visher, Stephen S. 217
Wagner, Frank Casper: Memorial 35
Water Mites of Lake Wawasee 315
Welch, Winona H. 65
Whitacre, Francis M. 187
White, John 37
Winter Meeting Program 10
Wright, Emerson Blane: Memorial 34
Zinszer, Harvey A. 263